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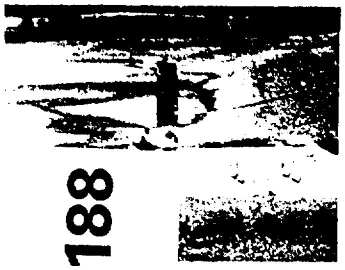

GEOPHYSICAL ASSESSMENT OF FOUNDATION CONDITIONS: RIGHT ABUTMENT MILL CREEK DAM

by

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Results of a comprehensive, integrated geophysical investigation of the right abutment area of Mill Creek Dam near Walla Walla, Washington, are presented. The damsite has experienced anomalous seepage since the first reservoir filling in 1941, despite remedial measures, including a concrete cutoff wall completed in 1983. Self potential surveys and other geotechnical investigations conducted in 1984 concluded that the major anomalous seepage paths were through the right abutment area. Sinkholes and cracks in the reservoir floor and right abutment and the presence of fines in drain discharges indicate that silt, which forms the floor of the reservoir and the abutments, is being piped through the foundation of the dam. A potential is also considered to exist for piping of dam materials into the foundation. The geophysical investigations and a concurrent drilling program were designed to detect anomalous conditions, e.g. cavities and low density zones, in the dam and dam foundation in the right abutment area.

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19. ABSTRACT (Continued).

The geophysical program included shallow, high resolution seismic reflection, ground penetrating radar, electrical resistivity, electromagnetic conductivity, and microgravity surveys. Interpretations of the results of the geophysical surveys consistently indicate two anomalous trends leading from the reservoir and apparently passing under the dam. The anomalous zones are interpreted to have low density and high water content and are located within a conglomerate formation, which lies below the Palouse Silt (loess) on which the dam is founded. The overall interpretation is only marginally confirmed by the exploratory drilling program--drilling stopped at the top of the conglomerate. A recommended confirmatory drilling program be presented.

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PREFACE

A geophysical investigation of foundation conditions of the right abutment area of Mill Creek Dam, Walla Walla, Washington, was authorized by the US Army Engineer District, Walla Walla (CENPW), under IAO No. E86890074, dated 4 April 1989. The work was performed during the period 4 April-30 September 1989.

Program planning, field work, data processing, and interpretation was accomplished by a team consisting of Messrs. Donald E. Yule, Michael K. Sharp, José L. Llopis and Dr. Dwain K. Butler, Engineering Geophysics Branch (EGB), Earthquake Engineering and Geosciences Division (EEGD), Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES). Personnel of CENPW performed location and elevation surveys for the geophysical survey lines. This work was performed under the general supervision of Mr. Joseph R. Curro, Chief, EGB, Dr. Arley G. Franklin, Chief, EEGD, and Dr. William F. Marcuson, Chief, GL. This report was prepared by Dr. Butler.

COL Larry B. Fulton, EN, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

	Page
PART I : INTRODUCTION	3
Background	3
Scope	4
PART II : GEOPHYSICAL SURVEY PROGRAM	5
Program Design	5
Geophysical Methods Concepts and Field Procedures	8
PART III : RESULTS AND INTEGRATED ASSESSMENT	21
Program Results	21
Integrated Assessment	53
PART IV : CONCLUSIONS AND RECOMMENDATIONS	57
Conclusions	57
Recommendations	57
REFERENCES	60
APPENDIX A : SEISMIC REFLECTION SURVEY	A1
APPENDIX B : GROUND PENETRATING RADAR SURVEY	B1
APPENDIX C : POLE-DIPOLE RESISTIVITY SOUNDING PLOTS	C1
APPENDIX D : MEASURED AND CORRECTED GRAVITY DATA	D1

GEOPHYSICAL ASSESSMENT OF FOUNDATION CONDITIONS
RIGHT ABUTMENT, MILL CREEK DAM

PART I : INTRODUCTION

Background

1. Mill Creek Dam, near Walla Walla, Washington, has experienced anomalous seepage since its first filling in 1941. Various attempts to abate and control the seepage, including construction of a concrete cutoff wall (completed in 1983), have been unsuccessful. As part of a test pool raise in 1984, WES installed a self potential array to monitor seepage conditions during the test. The results of the geophysical surveys and other geotechnical investigations indicate that the majority of the anomalous seepage is presently occurring through the right abutment of the dam, around the end of the cutoff wall (Butler, Wahl and Sharp, 1984). The geophysical surveys also indicated a possible minor seepage path under the embankment near the left abutment, where a deficiency may exist in the cutoff wall (the cutoff wall may not extend deep enough). Overall, the seepage has been reduced by 30 percent, from 33 ft^3/s (0.93 m^3/s) to 22 ft^3/s (0.62 m^3/s), since construction of the cutoff wall, and downstream flooded (saturated) farmland acreage has been reduced by 56 percent. However, seepage pressures in a conglomerate formation in the right abutment area have increased dramatically (Walla Walla District, 1987).

2. The dam foundation and abutments are silt (the Palouse silt or loess), which varies from 50 to 100 ft thick beneath the upstream toe of the dam. Below the silt are, successively, the conglomerate and a basalt. The conglomerate (alluvial) consists of coarse sand, gravel, cobbles, and zones of silt; while the conglomerate in the vicinity of the dam has no formal name, it is correlative to the Ringold Formation. The permeability of the conglomerate varies considerably both laterally and with depth in the formation. During the initial and subsequent reservoir filling events, sinkholes and cracks appeared in the reservoir floor and right abutment area. Also, significant quantities of embankment and/or foundation materials were piped through the dam's interior drainage system. The project history coupled with the altered seepage conditions caused by the presence of the cutoff wall lead to concerns about the safety of the dam during subsequent reservoir filling. A failure scenario for the dam is based on a model which includes piping of the silt foundation/embankment materials through the conglomerate leading to subsidence of overlying materials. Formation and growth of voids and subsidence in the foundation/embankment could threaten

the integrity of the dam. The basalt, the Frenchman's Springs Member of the Wanatum Basalt (Columbia River Basalt Group), is highly fractured in places and has portions which are vesicular.

3. Walla Walla District has proposed an impermeable membrane liner for the reservoir. Prior to approval of the design concept, additional foundation investigations including surface geophysical surveys were planned. WES was asked to plan a geophysical field program which concentrated on assessing foundation conditions in the right abutment area.

Scope

4. WES designed a geophysical field survey program to (1) assess general/overall subsurface conditions in the right abutment area, such as depth to formation interfaces and lateral condition changes, and (2) detect localized anomalous conditions, such as cavities, subsidence features, saturated zones, and any anomalous low density zones. Part II of this report describes the field survey program and rationale and presents a brief summary of each geophysical method employed at the site. Part III presents the results and interpretation of the geophysical program, and a summary and recommendations are given in Part IV.

PART II : GEOPHYSICAL SURVEY PROGRAM

Program Design

Site Specific Details

5. The stratigraphy of the foundation and right abutment is known to the extent illustrated in Figure 1 (from a Draft Design Memorandum, Walla Walla District, 1987), however the distribution of physical properties of the silt and conglomerate is uncertain. The permeability of the conglomerate, which consists of coarse sand, gravel, cobbles, and zones of silt, for example, is known to vary considerably. The variable permeability of the conglomerate is directly related to the degree of cementation. Also, the nature of anomalous conditions, if they exist at all, implied by the failure scenario is completely uncertain. Piping of the silt into the underlying conglomerate could produce voids in the silt formation, but more likely the piping would result in a progressive collapse feature which would migrate upward and laterally away from the location where the silt enters the conglomerate. Within the silt then, the effect would be to produce anomalously low density zones. Within the conglomerate, the anomalous seepage would carry downstream not only the material removed from the silt above but material removed from within the conglomerate itself, such as fines from within the matrix of uncemented zones of conglomerate or from silt pockets in the conglomerate. The net effect would be to produce zones of anomalously low density and/or higher water content within the conglomerate.

6. The most obvious physical effect of the piping/collapse model will be the creation of low density zones in the silt and conglomerate. Electrical resistivity and conductivity (resistivity = 1 / conductivity) depend intimately on porosity and water content (saturation). The piping should produce zones of increased porosity and, where the zones are below the water table, increased water content. Also, the zones of increased porosity may retain water from rainfall infiltration and anomalous seepage. The higher porosity/water content zones will produce low resistivity/high conductivity anomalous zones. Where the anomalous zones in the silt are saturated, high seismic velocity zones will be created.

7. It was difficult in the geophysical program planning phase to optimize a program for the site, since nothing was known about such geophysical parameters as density, electrical resistivity, and seismic velocity of the silt, conglomerate and basalt. Also, as discussed above, the details of anomalous conditions associated with the anomalous seepage are unknown. Thus the geophysical program had to be planned to include a range of

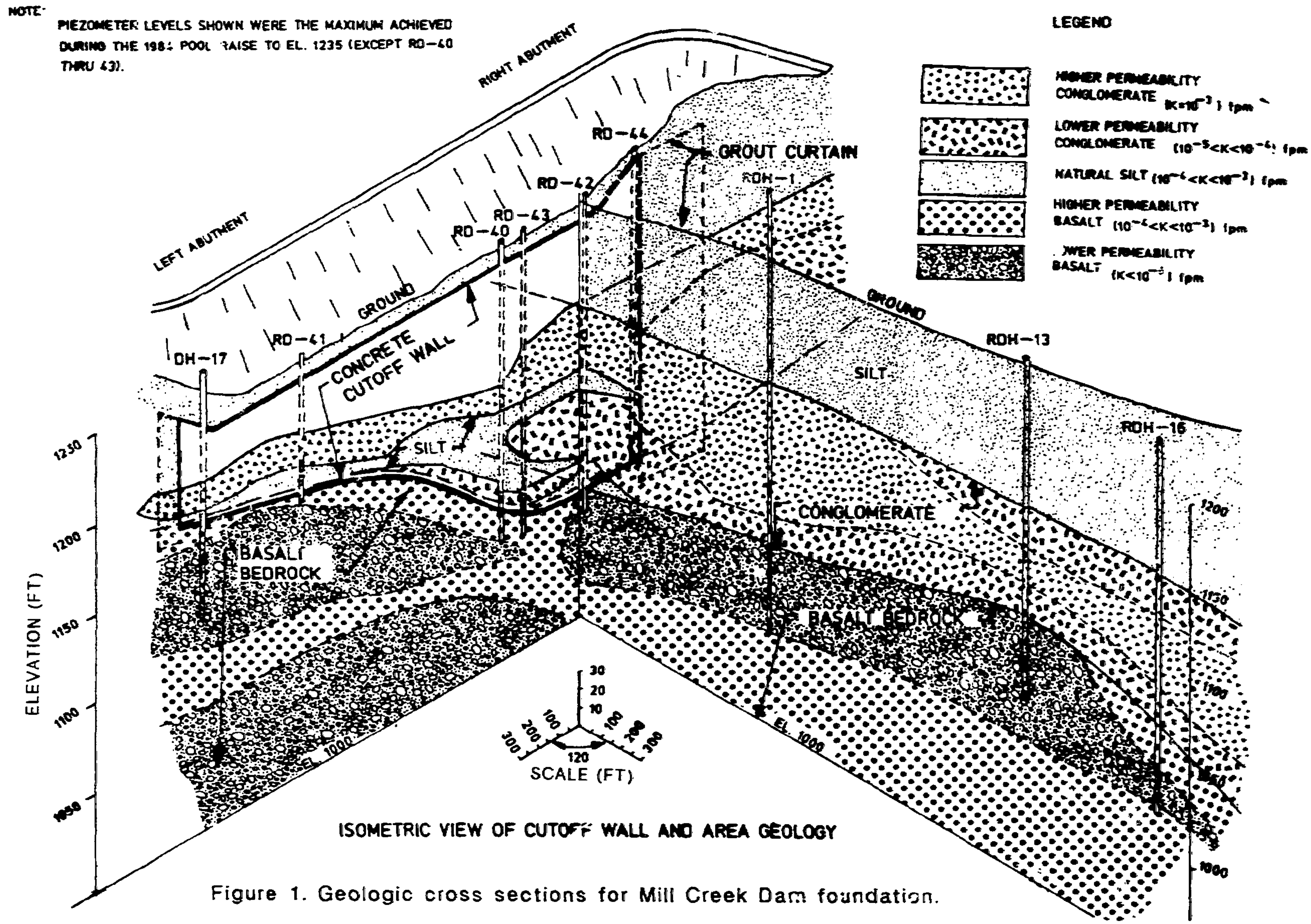


Figure 1. Geologic cross sections for Mill Creek Dam foundation.

in situ condition possibilities. The strategy was to apply complementary geophysical methods and to achieve high resolution subsurface coverage both vertically and laterally.

Complementary Geophysical Program

8. The geophysical program includes the following methods: seismic reflection (SR), ground penetrating radar (GPR), electromagnetic conductivity (EM), electrical resistivity (ER), and microgravity (MG). If site conditions are such as to allow sufficient depth of investigation (penetration), the GPR method holds the potential for continuous lateral coverage and the highest resolution of any of the geophysical methods. Depth of investigation for GPR varies greatly from site to site, from as much as 50 ft to less than 3 ft depending on the ground conductivity (penetration decreases as conductivity increases). Clays, high water content and shallow water tables are site factors which can limit GPR penetration. Localized features as small as 2-3 ft effective diameter can generally be detected within the effective depth of investigation, if the features are conductive or highly resistive relative to the surrounding material. GPR is also highly effective for profiling interface depth variations. Seismic reflection complements GPR in providing relatively high resolution laterally and vertically, however SR has consistently greater depth of investigation capability. SR has the potential for detecting localized features as small as 10-15 ft in effective diameter. Objectives of the SR and GPR surveys are to map interfaces between the silt/conglomerate and conglomerate/basalt and to detect localized anomalous conditions such as voids or collapse structures.

9. EM and ER are complementary in the sense that the methods respond with different sensitivities to high and low resistivity/conductivity anomalies. EM can be used to profile long distances rapidly and is sensitive to high conductivity localized features. ER is well suited to both vertical property variation detection and horizontal profiling, and is approximately equally sensitive to high and low resistivity anomalies. ER surveying is more labor intensive than EM surveying. ER and EM survey objectives are to map variations in material properties such as porosity and water content and to detect localized anomalies such as voids and collapse features.

10. Microgravity surveying gives a positive indication of low and high density anomalous conditions in the subsurface. Coupled with the EM and ER results, the results of microgravity surveys allow a higher probability anomaly identification: such as, air-filled versus saturated higher porosity zone (cavity or

collapse feature); cemented, low porosity/permeability conglomerate versus uncemented, high porosity/permeability conglomerate.

Program Layout

11. Figure 2 is a site location map of the right abutment showing geophysical survey lines. The survey lines were established to provide continuous coverage along the length of the embankment and approximately perpendicular to the axis of the embankment in the right abutment area. Survey lines C-F begin at a location approximately 240 ft from the end of the cutoff wall near station 32+20. Walla Walla District survey personnel located the lines and determined elevations and coordinates of survey points. For lines C-F, elevations were determined every 10 ft and coordinates every 20 ft. Stations are numbered consecutively along each survey line, beginning from the end nearest the cutoff wall. Odd-numbered stations are indicated by an offset numbered stake and a wooden hub or steel spike driven flush with the ground surface. Even-numbered stations are indicated by a paint spot. Along the crest, line B begins at borehole RDH-6, and stations are located every 20 ft along the center of the access road.

12. In addition to the profile lines in Figure 2, a survey grid was established around a sinkhole as illustrated in Figure 3. The sinkhole is located in the floor of the reservoir just off the Figure 2 site map, 200 ft NE of the end of line D (D59) and 250 ft nearly due east the end of line F (F65). The sinkhole survey grid was established and elevations determined by WES personnel. The sinkhole is approximately 10 ft in diameter and 3 ft deep. Apparently the present sinkhole is in the vicinity of a previous sinkhole which was filled.

13. The complete geophysical program plan is summarized in Table 1, which indicates the survey line length, measurement stations, and the geophysical methods applied along each line.

Geophysical Methods Concepts and Field Procedures

14. No attempt will be made to thoroughly review the physical concepts of the geophysical methods. For each method, a very brief concept statement is given and the specifics of the field procedure for this site presented. For each method, reference will be made to specific readily available WES technical reports or other appropriate sources. General references for geophysical methodology are Department of the Army (1979) and Telford et al (1976).

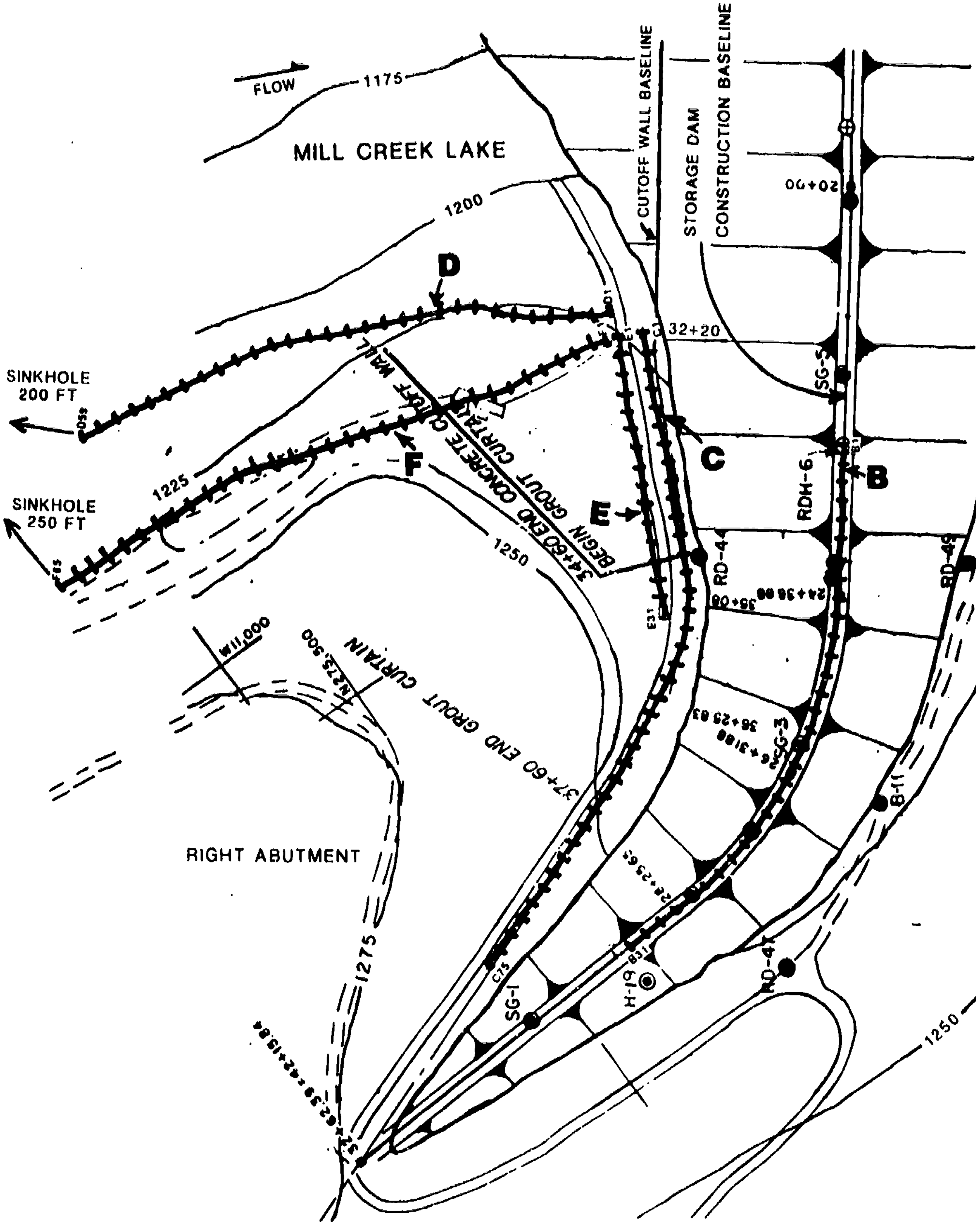


Figure 2. Map of right abutment area showing geophysical survey lines.

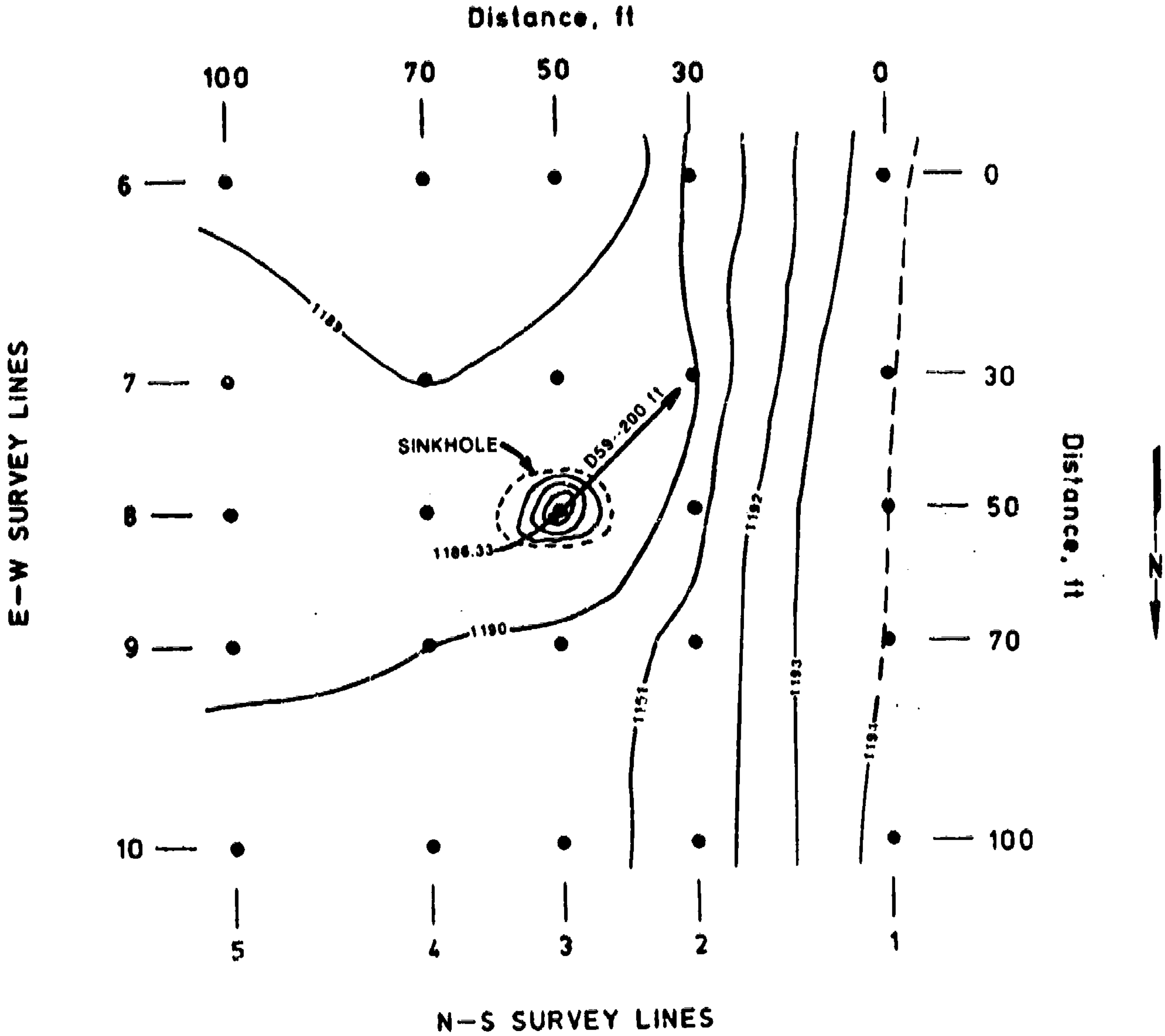


Figure 3. Survey grid around sinkhole. Elevation contour interval = 1 ft.

Table 1

Geophysical Program

Survey Line/Area	Line Length (Stations)	Geophysical Methods*
B	600 ft (B1-B31)	MG
C	740 ft (C1-C75)	SR, GPR, ER, EM, MG
D	580 ft (D1-D59)	GPR, SR, MG
E	300 ft (E1-E31)	GPR, EM, MG
F	640 ft (F1-F65)	GPR, EM, MG
Sinkhole	100 x 100 ft survey grid	GPR, EM, MG

*MG--microgravity; SR--seismic reflection; GPR--ground penetrating radar; ER--electrical resistivity; EM--electromagnetic conductivity.

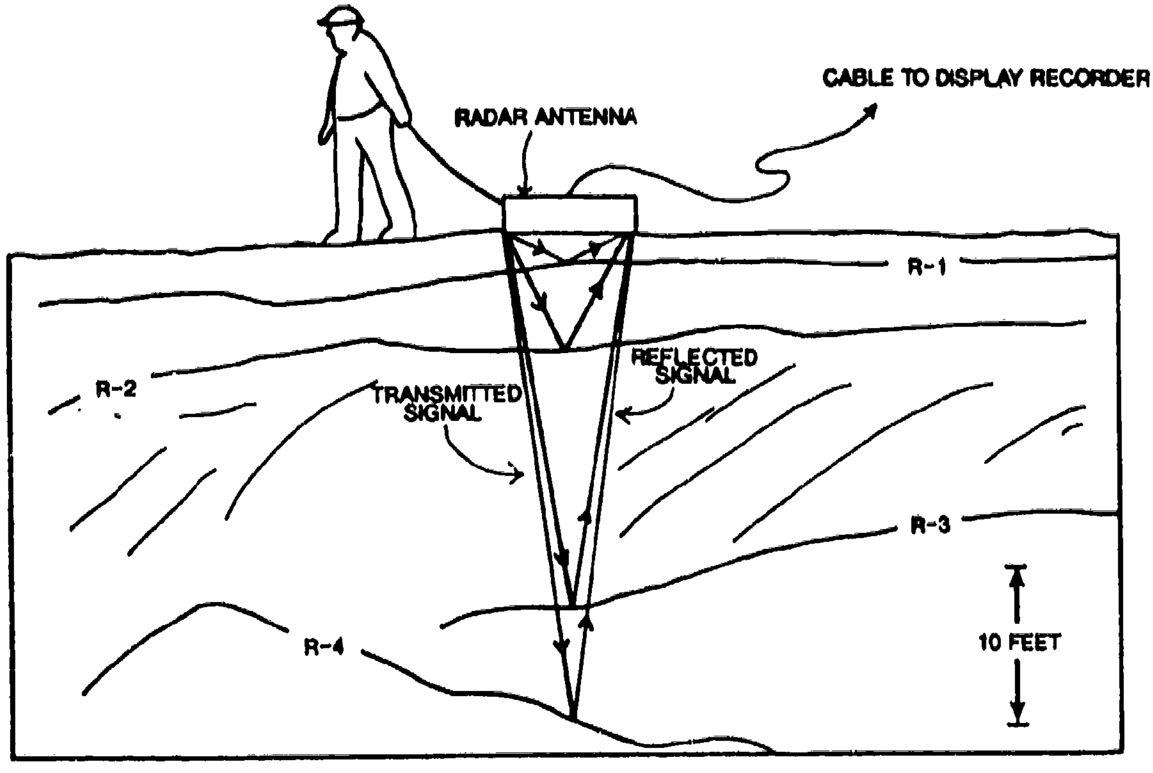
Seismic Reflection

15. The seismic reflection method has been a cornerstone of petroleum exploration for decades, and recent advances in seismic instrumentation and microcomputers make it feasible to apply the same methodology to geotechnical problems (shallow depths of investigation, from as shallow as a few feet to several hundred feet). Seismic reflection involves near vertical propagation paths in the subsurface, contrasted to the seismic refraction method which utilizes horizontal travel paths, and seeks to identify reflections from subsurface interfaces or localized anomalous features. The practical implication of the near vertical propagation paths is that the distances from the seismic source to the farthest geophone is much shorter than for seismic refraction for the same depth of investigation. Thus seismic reflection can be effectively applied at sites with limited horizontal access, such as dams sites. Dobecki et al (1989) discuss the seismic reflection method and its application at a Corps' dam site.

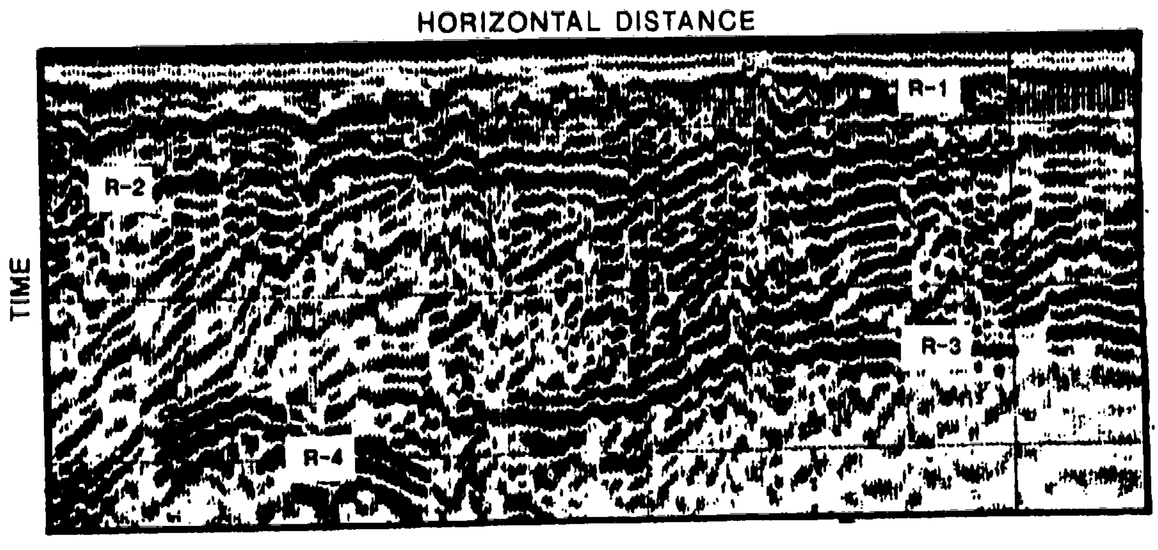
16. Two different 24-channel seismographs were tested. Three seismic sources, a 20-lb sledge hammer, a downhole 30-06 rifle, and a downhole .50 caliber rifle, were tested at several different filter settings of the seismographs. The field parameter selection array (geophone layout) consisted of 24 takeouts at 2-ft spacing, where each takeout was connected to three closely spaced 40-Hz geophones in series. Field parameter selection tests were conducted at three locations, two locations on line C and one location on line D. At each location the individual sources were tested at various filter settings and at offset distances ranging from 2 to 96 ft from the closest geophone. This parameter selection test procedure is termed a walkaway test. For each source and filter setting tested, the walkaway test resulted in records covering either 96 or 144 ft laterally. The work was performed by Great Plains Geophysical, Lawrence, Kansas.

Ground Penetrating Radar

17. The GPR method produces a continuous profile of electromagnetic (radar) reflections from subsurface features. This is accomplished by towing a radar antenna at a walking pace along the desired survey line. The antenna is connected to a controller/processor and graphic recorder mounted on a cart or field vehicle. During the traverse along the survey line, the antenna alternately transmits and receives radar pulses (120 MHz center frequency). The received signals represent reflections (near vertical propagation paths) from subsurface features. The received signals are displayed on the graphic recorder as a record of signal amplitude versus time ("radargram"). Figure 4 illustrates the GPR technique (Sylvester, 1989). The pulse is



a. GPR survey over a geologic section with four reflectors (R-1 -- R-4).



b. Graphic radar record ("radargram") for geologic section in a.

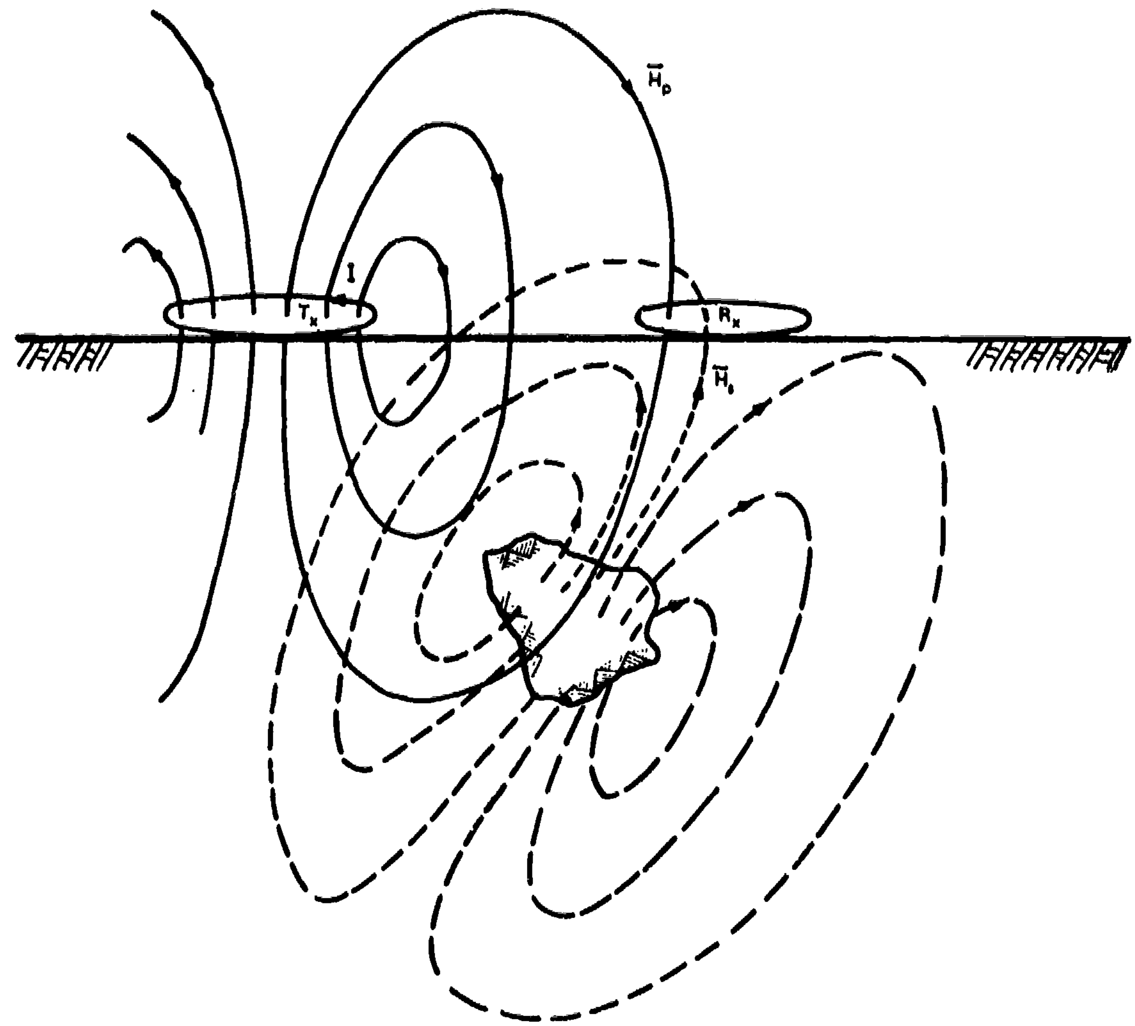
Figure 4. Illustration of GPR technique and graphic radar record.

repeated and the antenna is towed at a rate which gives 3-4 vertical records (soundings) every foot along the survey line. Along lines C-F, records were obtained using 100 and 300 nanoseconds (ns) total record time, i.e., two traverses were performed along each line. Twelve survey lines were traversed in the area of the sinkhole; record time was 150 ns, except for line 1 at 200 ns. As the antenna is towed, manually triggered horizontal distance indicator marks are produced on the record as each survey stake is passed. Ballard (1983) discusses the concepts of the GPR method and presents examples of GPR records over subsurface features such as cavities. The GPR work was performed by Williamson and Associates, Seattle, Washington.

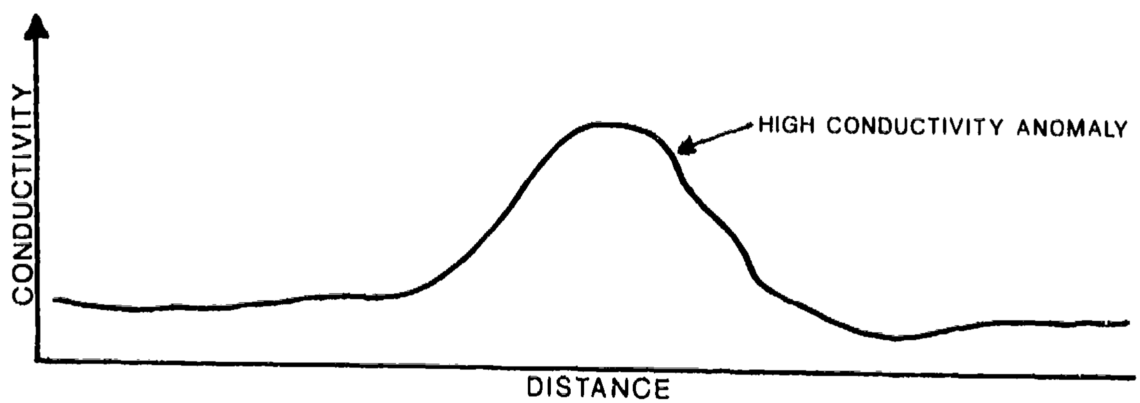
Electromagnetic Conductivity

18. The EM method involves the determination of an apparent ground conductivity from measurements with a system that consists of an electromagnetic loop transmitter and a loop receiver. The transmitter emits a constant frequency signal (the primary signal) at 400, 1600 or 6400 Hz. The receiver detects a signal that consists of the primary signal plus a secondary signal. The secondary signal arises from interactions with subsurface materials and features through the process of electromagnetic induction. A ratio of the secondary signal to the primary signal is then formed by the receiver electronics. The ratio is proportional to the apparent ground conductivity, and the receiver displays a reading in conductivity units (millimhos/m = 10^{-3}/ohm-m, where ohm-m are the units of resistivity). If the subsurface were a uniform material to a great depth, the apparent ground conductivity would equal the true conductivity of the material. In general however, the conductivity reading is a weighted average of all material within the volume of investigation. The volume of investigation and hence the depth of investigation depends primarily on the transmitter and receiver loop separation and the transmitter frequency. The basic concept of EM surveying is illustrated in Figure 5.

19. Loop separations of 10 m, 20 m, and 40 m are used respectively for the three transmitter frequencies listed above. For each loop separation, measurements can be made for two loop orientations: horizontal loops (vertical dipoles, VD), and vertical loops (horizontal dipoles, HD). Thus at each location six different measurements can be made. The approximate depths of investigation for the six measurements are listed below:



a. Illustration of inductive coupling with a subsurface conductive feature, for horizontal loops/vertical dipoles.



b. Apparent conductivity profile across conductive feature.

Figure 5. Illustration of the EM surveying technique: Tx--transmitter; Rx--receiver; Hp--primary magnetic field; Hs--secondary magnetic field.

Loop Spacing	Depth, m (ft)	
m (ft)	HD	VD
10 (33)	7.5 (25)	15 (50)
20 (66)	15 (50)	30 (100)
40 (130)	30 (100)	60 (200)

Within the approximate depths of investigation listed above, the HD measurements are the most sensitive to shallow material. All six measurements were made at 10 ft intervals along lines C,E and F. The transmitter was placed at the survey line station for each set of measurements. Thus, following the convention of assigning the measurement to the midpoint of the loop separation, measurements with the three loop separations will be displaced different amounts from each survey line station in data plots. Butler (1986) discusses the EM method and presents examples.

Electrical Resistivity

20. ER methods are used generally to determine vertical (vertical sounding) or lateral (horizontal profiling) profiles of electrical resistivity of the subsurface. The method used for the present investigation utilizes a pole-dipole electrode array and is actually a combined vertical sounding/horizontal profiling method. Field procedure and interpretation method are a modification by Bates (1973) of a methodology first proposed by Bristow (1966). Details of field procedures, data processing methods, and interpretation concepts are given by Butler et al (1982). The major disadvantages of the pole-dipole method of Bristow and Bates are the very labor intensive data acquisition procedure and the subjective interpretation procedure. The major advantages are that the interpretation procedure locates anomalies in cross section and gives an indication of size and shape. Numerous case studies indicate successful application of the method to detection and delineation of subsurface cavities.

21. A pole-dipole resistivity survey was conducted along line C. Beginning at station C1, current electrode stations were established every 50 ft along the line. A second current electrode was placed approximately 1000 ft distant which remained fixed during the survey. For each current electrode station along the line, two vertical soundings are performed by moving a potential electrode pair, separated by 10 ft, along the profile line from 10 ft to 200 ft on each side of the current electrode. The resulting data set is extensive and has considerable redun-

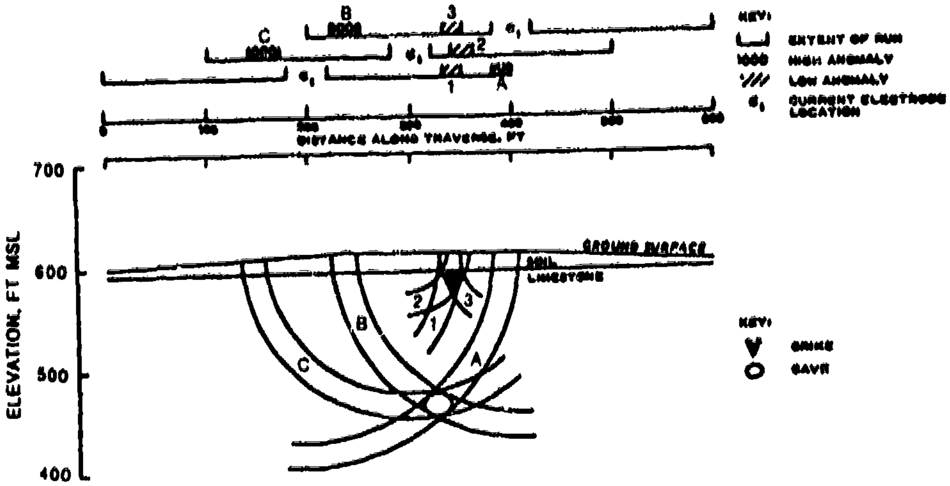
dancy. The vertical soundings are examined and vertical variation trends are determined. For each sounding, high and low resistivity anomalies relative to the trend are identified. Using the procedure discussed in Butler et al (1982) the anomalies are located on a cross section beneath line C. Anomalies are defined in terms of profile location, depth and approximate shape and size. The graphical interpretation technique is illustrated in Figure 6a, and an example of the sounding curves and interpreted cross-section for a survey across an air-filled cavity system is shown in Figure 6b,c (Butler et al 1982).

Microgravity

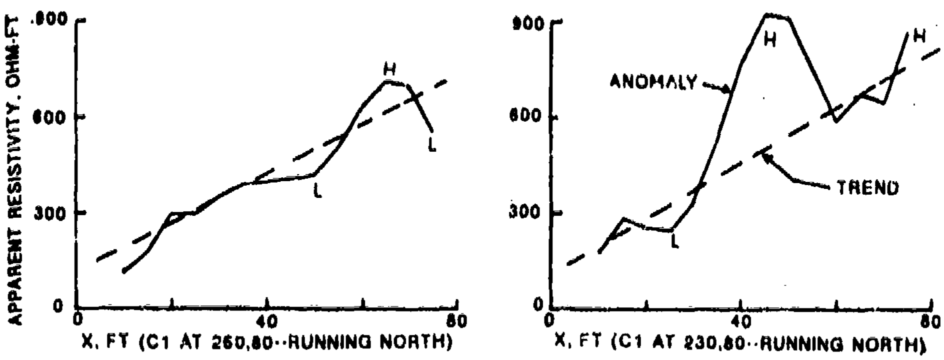
22. The microgravity method involves relative measurements of the acceleration or force of gravity on the surface with high accuracy and precision. A gravity meter is used with an instrument sensitivity of 1 microgal, where 1 microgal = (10^{-9} x g) and g is the normal earth's gravitational acceleration of 980 cm/s^2 (32 ft/s^2). After applying various corrections, the gravity data are presented in profile plots or contour plots. If the subsurface is uniformly, horizontally layered beneath the survey site, for example, the measured gravity field would be a constant or perhaps be slowly varying (termed the regional gravity field component) over the site due to deep geologic conditions. The presence of any lateral density changes at shallow depths beneath the site will produce gravity anomalies which will perturb the constant or slowly varying regional gravity field. For example, a 2 m (6.6 ft) diameter spherical-shaped, air-filled cavity in soil can be detected to a depth of about 4 m (13 ft), whereas a 2 m diameter horizontal, cylindrical-shaped, air-filled cavity can be detected to a depth of about 9 m (30 ft). Figure 7 illustrates the concept of a gravity anomaly produced by a subsurface density anomaly and shows gravity anomalies over spherical and cylindrical features for three depths. Note that the anomaly magnitude decreases as depth increases, while the spatial extent of the anomaly increases as depth increases.

23. Butler (1980) describes the field procedures and data corrections required for microgravity surveying. The data must be acquired using a very careful and consistent field procedure which involves an exacting measurement sequence, repeated observations at 20 percent or more of the stations, and repeated occupations of base stations at 30-45 minute intervals. Data corrections include:

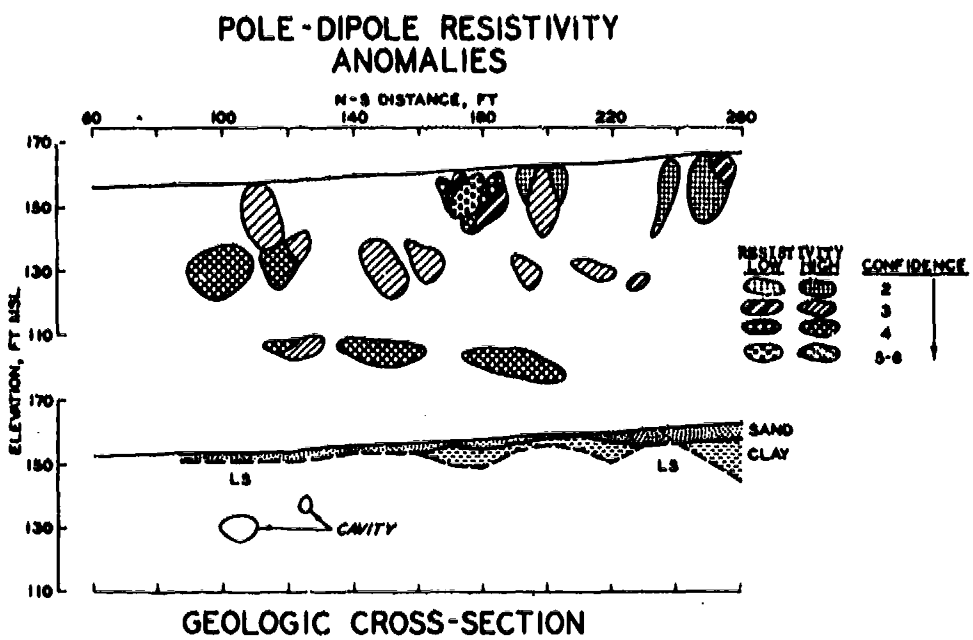
a. Time variations of measured gravity which consist of instrument drift and earth tide variations; base station reoccupations are utilized for this correction procedure;



a. Graphical interpretation method for pole-uipole resistivity surveys.

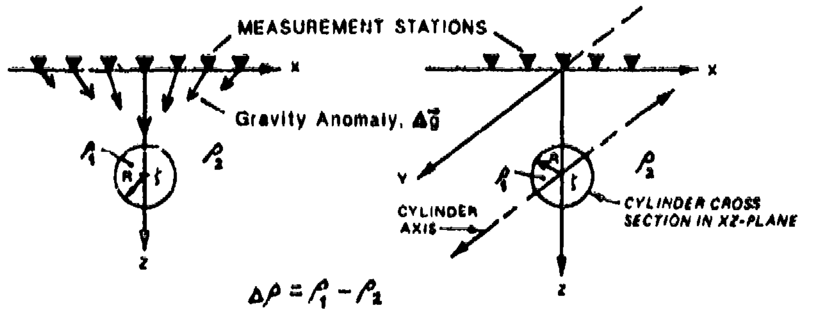


b. Pole-dipole resistivity sounding curves.



c. Comparison of resistivity cross-section with geologic cross-section.

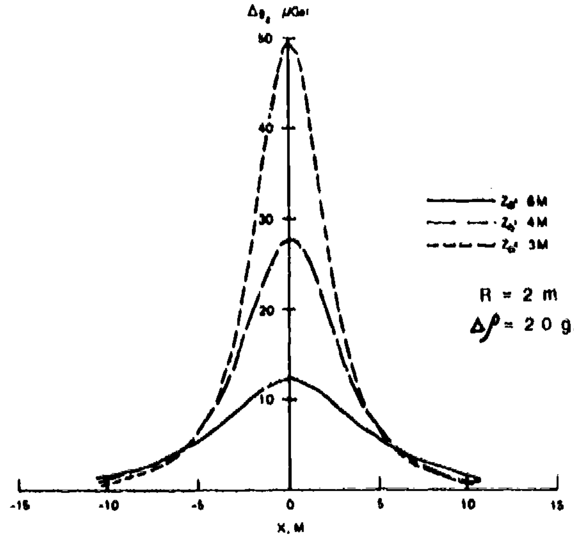
Figure 6. Illustration of the pole-dipole resistivity interpretation procedure and a field example.



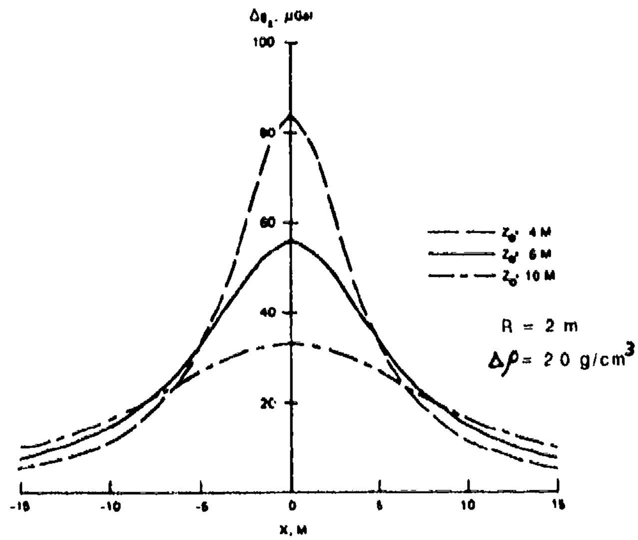
GEOMETRY OF SPHERICAL MODEL

HORIZONTAL CYLINDRICAL MODEL GEOMETRY
MODEL GEOMETRY

a. Concept of gravity measurements across an anomaly. A density anomaly $\Delta\rho$ produces a gravity anomaly $\Delta\vec{g}$. The gravity meter measures the vertical component Δg_z.



b. Gravity anomalies across a spherical model for three depths Zo.



c. Gravity anomalies across a cylindrical model for three depths Zo.

Figure 7. Illustration of gravity anomalies produced by simple models of subsurface features.

b. Latitude variations of gravity, i.e., correction for distance north/south of a base station;

c. Elevation variation along survey lines;

d. Terrain surrounding the survey area.

The terrain correction for a survey site such as Mill Creek Dam s quite involved, requiring consideration of terrain variations to a distance of several kilometers; although it is only terrain features within several hundred meters of a measurement station which must be modeled carefully. Gravity and topographic data from the survey were taken to the Branch of Geophysics, U.S. Geological Survey, Denver, for terrain correction calculations using a mainframe computer program. The remainder of the gravity corrections were made using microcomputer programs described by Butler and Yule (1984). Gravity data which has been corrected for the above considerations is termed the Bouguer gravity. If the constant or slowly varying regional gravity field is subtracted from the Bouguer gravity, the remainder is termed the residual gravity, and anomalies are termed respectively Bouguer and residual anomalies.

PART III : RESULTS AND INTEGRATED ASSESSMENT

Program Results

Seismic Reflection

24. A total of 101 field parameter selection tests were conducted at the three locations (source locations at C13, C41, and D35). The objectives of the tests were to select source type, geophone type (natural frequency) and arrangement, and seismograph filter settings in order to optimize and enhance the detection and identification of reflections. Generally, if the shallow SR method is suitable for the geotechnical objectives at a site, reflection events can be identified and enhanced during this test phase. The optimum set of field parameters will then be used for the remainder of the reflection survey unless conditions change significantly.

25. In all of the test records, only one event is noted which is considered to be a reflection. The reflection event is indicated in Figure 8 in a record section for location C13. This event has a normal moveout velocity of 3730 ft/s (1137 m/s) and represents reflection from an interface at a depth of 170 ft. The normal moveout velocity represents an "average" of the seismic velocities of all the material <u>above</u> the interface. The reflection is probably from the conglomerate-basalt contact, and the depth is consistent with drilling results (Walla Walla District 1987). No reflection event from the silt-conglomerate contact is observed. The lack of identifiable reflections indicates that the acoustic impedance (product of bulk density and seismic velocity) contrast across the silt-conglomerate contact must be small. This lack of acoustic impedance contrast likely indicates that the conglomerate is uncemented at the three locations tested. Also, the contact may be gradational and irregular laterally; both conditions would tend to degrade the quality of the SR records. Figures 9 and 10 present typical records from locations C41 and D35, and the contractor's report is included as Appendix A.

26. Refraction events are present on all records at the three locations; however, due to the short seismic survey line lengths, the refractions are from interfaces (material type or condition changes) shallower than the silt-conglomerate contact. The following tabulation summarizes the refraction interpretations for the three locations:

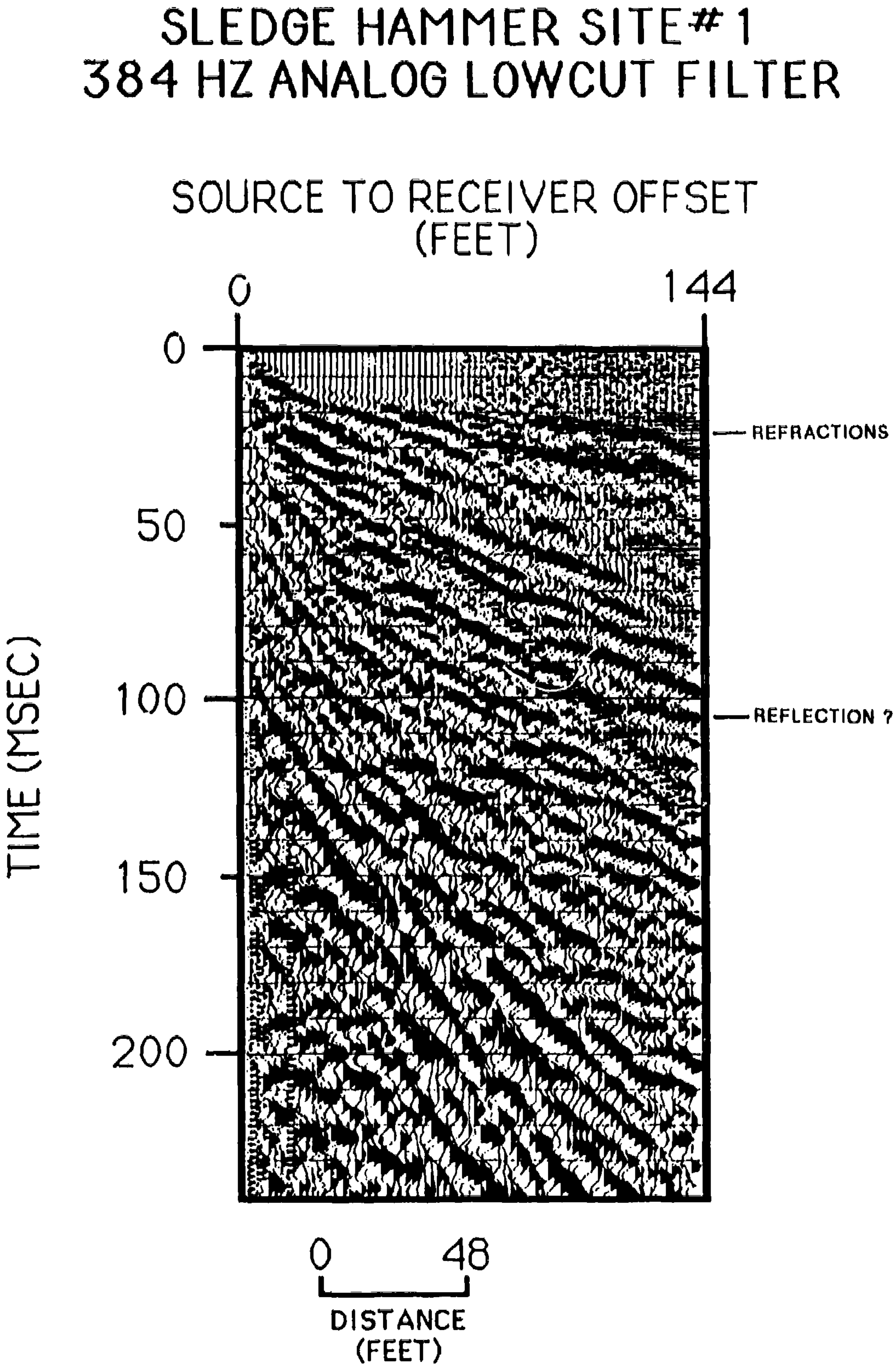


Figure 8. Walkaway seismic test, line C, location C13.

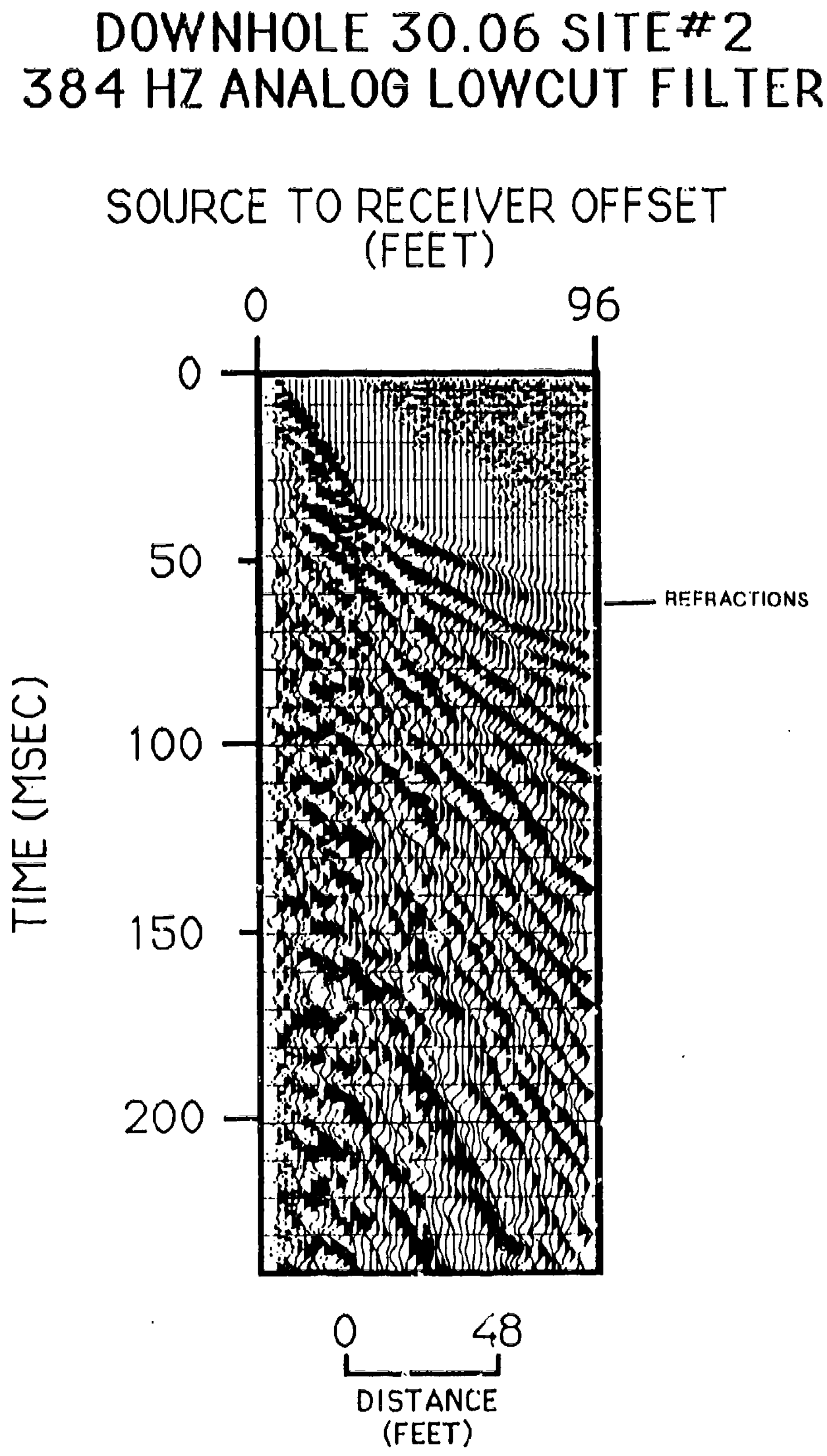


Figure 9. Walkaway seismic test, line C, location C41.

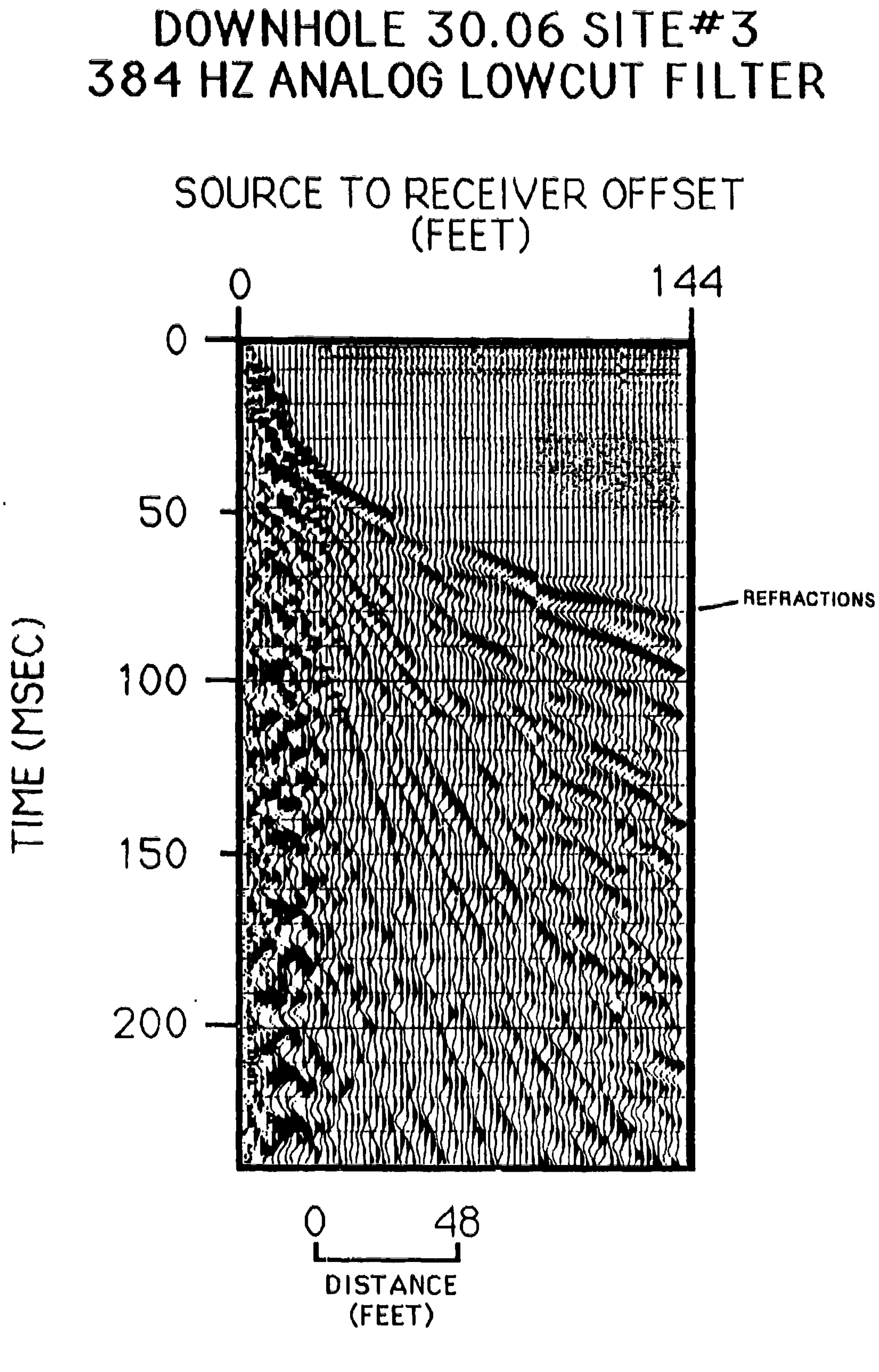


Figure 10. Walkaway seismic test, line D, location D35.

Seismic Refraction Results

C13 Velocity (ft/s)	C13 Depth (ft)	C41 Velocity (ft/s)	C41 Depth (ft)	D35 Velocity (ft/s)	D35 Depth (ft)
1500		750		650	
--------	5	--------	9	--------	10
4800		1400		1850	

Thus the compression wave (P-wave) velocity range of the surface layer ("soil") is 650 - 1500 ft/s (198 - 457 m/s) and the velocity range of the underlying material (silt/loess with varying water content and calcite content) is 1400 - 4800 ft/s (427 - 1463 m/s). The 4800 ft/s velocity at the first site (C13) is clearly anomalous, and likely represents a refraction off the top of the concrete cutoff wall. The maximum interface depth at which a second interface refraction might have been detected by the seismic surveys is approximately 50 ft (15 m).

Ground Penetrating Radar

27. Due to the relatively high conductivity/low resistivity of the near surface materials at the site, the maximum depth from which radar reflections are evident is 20-30 ft. The GPR surveys along lines C-F indicate predominately uniform conditions and thus do not indicate many shallow anomalies. While the GPR results are not useful for mapping the silt-conglomerate interface or for detecting cavities near that interface, it is possible that the shallower events on the radar records could be indicative of deeper anomalous conditions. The GPR surveys in the vicinity of the sinkhole, however, contain a tremendous amount of information indicating subsurface variation/anomalous conditions in the upper 20-30 ft.

28. The contractor's report is included as Appendix B and contains all graphic radar records. Only representative records will be presented in this section. Figure 11 is the record for the GPR survey along line E and is typical of the results for lines B-F, indicating no significant subsurface anomalous conditions. A synopsis of features of the GPR records for lines C-F is given in Table 2. Three interpretation guidelines used in preparing this synopsis are:

a. Interfaces between different materials will produce reflection events on the graphic record which vary in record time in relation to variations in depth to the interface (depth = 0.5 x t x C ; where t is the event time from the record, and C is the speed

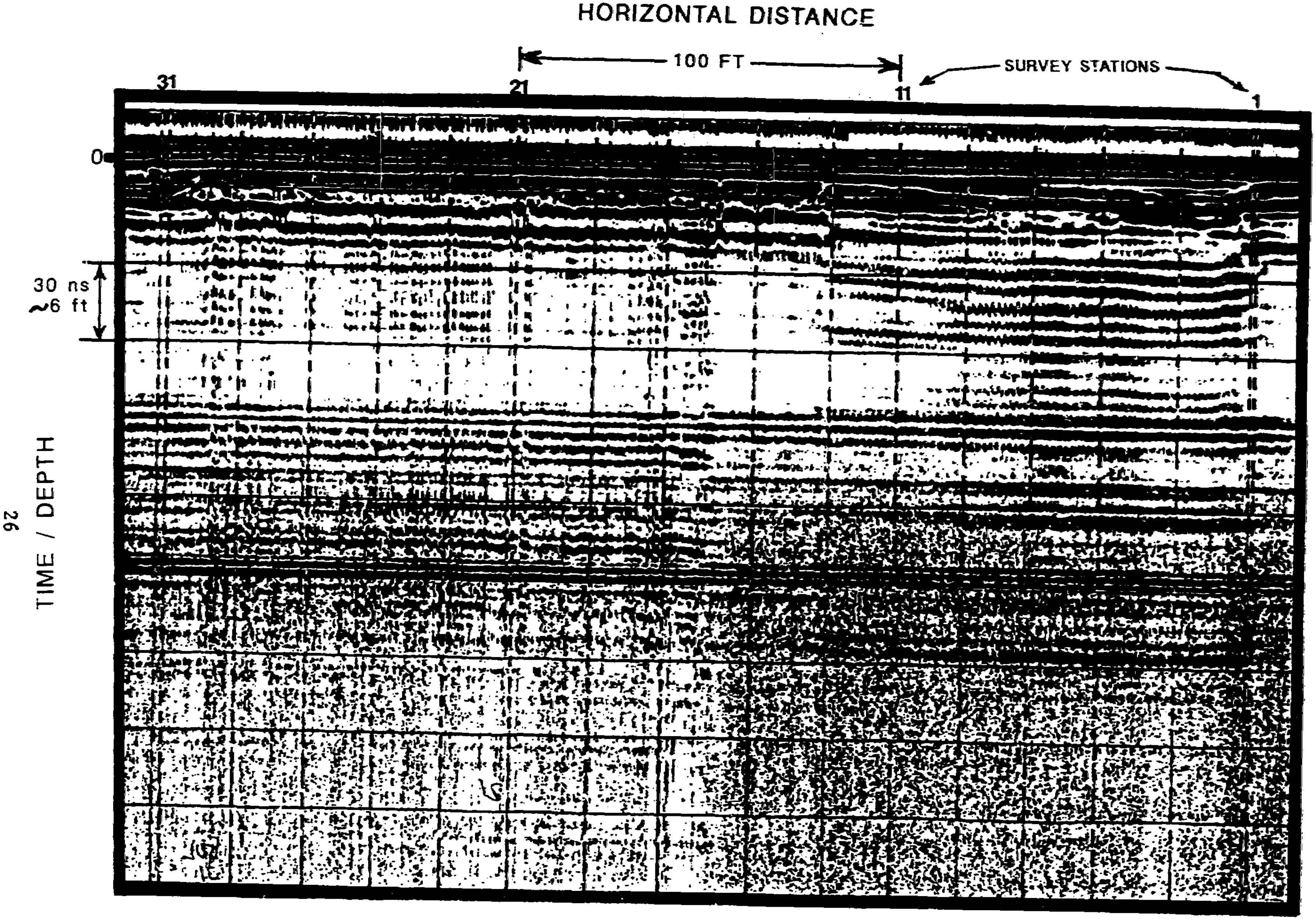


Figure 11. GPR record for line E.

Table 2

Synopsis of GPR Results -- Lines C-F

LINE C

Anomaly Location	Description
General	Thin surface layer (1 to 3 ft thick) along entire line. Below this reflector, materials are generally uniform, with occasional diffractions and small areal extent reflection events.
C2-C6	Disturbed area/shallow depression, approx. 5 ft depth.
C49-C63	Shallow subsurface depression.
C1-,C11,C36, C42,C60	Small, shallow diffractors, 3-10 depth

LINE D

Anomaly Location	Description
General	Thin surface layer (1 to 3 ft thick) along entire line. Very uniform conditions to depth of approx. 20 ft.
D31-D35	Shallow disturbed area, 3-5 ft depth.
D9	Small, shallow diffractors.

LINE E

Anomaly Location	Description
General	Thin surface layer (1 to 3 ft thick) along line.
E1-E13	Presence of pavement produces ringing on record.
E16,E30	Small, shallow diffractors.

(Continued)

Table 2 (Concluded)

LINE F

Anomaly Location	Description
General	Thin surface layer (1 to 4 ft thick) along entire line and generally uniform conditions to depth of approx. 20 ft.
F2	Several, small, closely-spaced diffractors, approx. 5 ft depth.
F13-F21	Ringing on record due to surface pavement.
F14	Small diffractors, 8-10 ft depth.
F42	Small diffraction apparently due to water well casing, located approx. 15 ft horiz.
F65	Small depression, approx. 5 ft depth, with apparent diffraction below.

of electromagnetic waves in the subsurface or approximately 4 x 10^8 ft/s or 1.2 x 10^8 m/s);

b. Changes in material type or condition (e.g., water content, grain size, cementation, clay content) along the interface will produce changes in the character/appearance of the reflection event and in some cases a breakup in the continuity of the event;

c. Localized features, e.g. cavities, boulders/cobbles, caliche zones, low density zones, high porosity/ water content zones, etc., with size <u>of the order</u> of the electromagnetic wavelength (approx. 3 ft) will produce a hyperbolic-shaped event (diffraction) on the record which opens downward in time.

29. If the interpretation of the GPR records for lines C-F is simple due to lack of detail on the records, then the interpretation of the records for the sinkhole GPR surveys is very difficult due to the considerable detail exhibited in the records. Figure 12 is the GPR record for E-W line 10, located 50 ft N of the sinkhole. This record illustrates the detail and complexity exhibited by most of the sinkhole GPR records. The most prominent feature of Figure 12 is a basin-like structure centered on N-S cross line 4; depth to the apparent bottom of the structure is 6 ft. Considering only the structure revealed in Figure 12, it could be a filled sinkhole or shallow channel. Beneath the basin structure is a complex of diffractions and dipping events, and the trough-like depression between cross lines 3 and 4 is possible evidence of a migration/piping pathway. Two other features between cross lines 4 and 5 resemble vertical pipes. The GPR record for N-S line 5 is presented in Figure 13, and exhibits a basin-like structure which extends S of the extent of the GPR survey line. Also, the vertical pipe feature nearest cross line 5 in Figure 12 appears in Figure 13 near cross line 10 as expected and suggests that the feature is 'quasi-circular' in horizontal section and not elongate.

30. In order to summarize the sinkhole GPR surveys, a three dimensional fence diagram of the major structures revealed by the records is shown in Figure 14, and a plan map of smaller scale anomalies, such as the vertical pipe features discussed above, is presented in Figure 15. The trends of the major structure in Figure 14 are (1)a dip to the east produced by 2-3 N-S 'escarpment-like' steps and (2)a more uniform dip to the south. The overall dip of the major reflector is to the SE. The survey area is too small to determine if the major structure is a buried channel trending to the SE or a large, filled sinkhole. Based on elevations of the top of the conglomerate (1180 ft in RDH-1) in drillholes located several hundred feet to the W of the sinkhole,

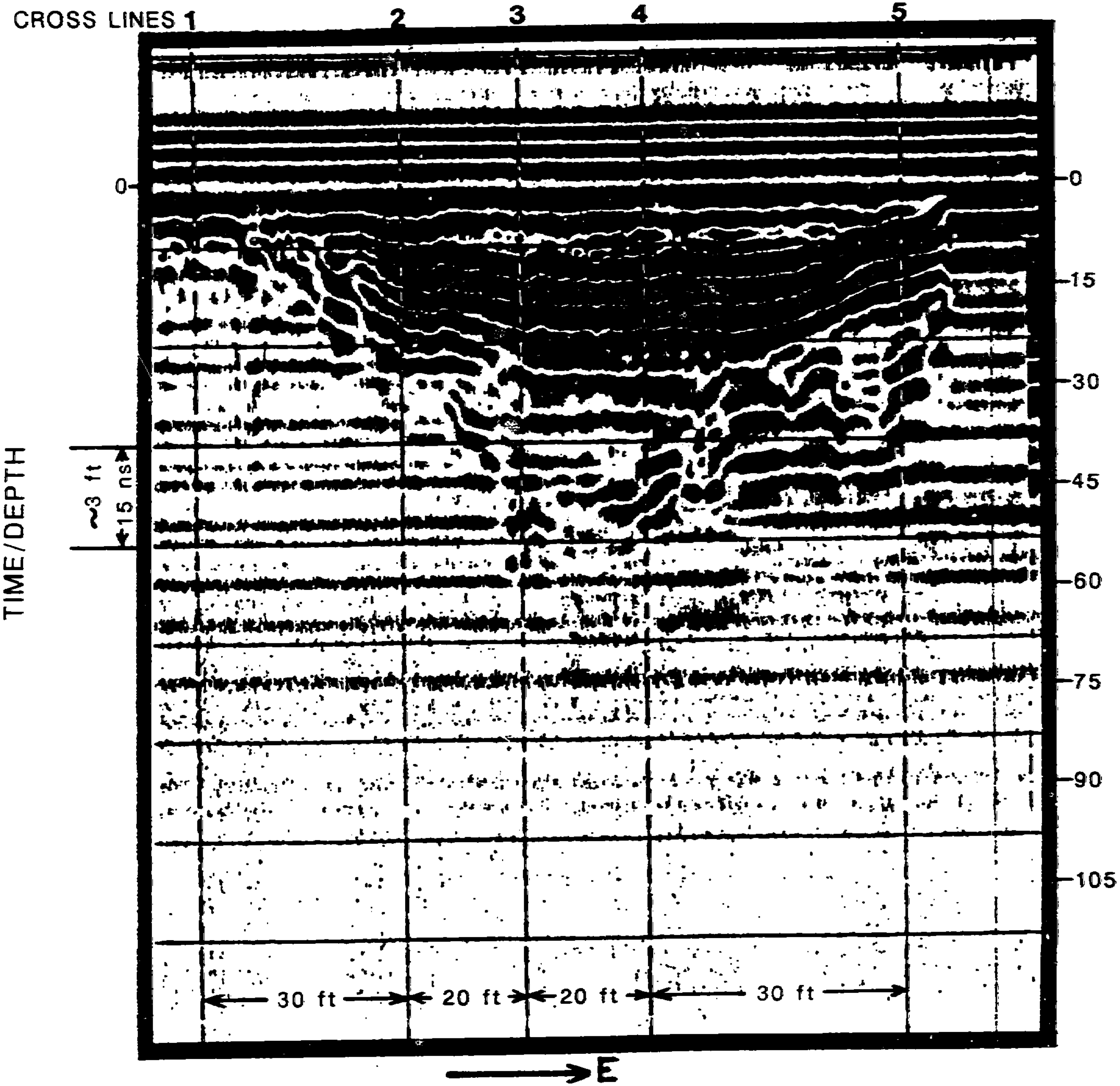


Figure 12. GPR sinkhole survey line 10.

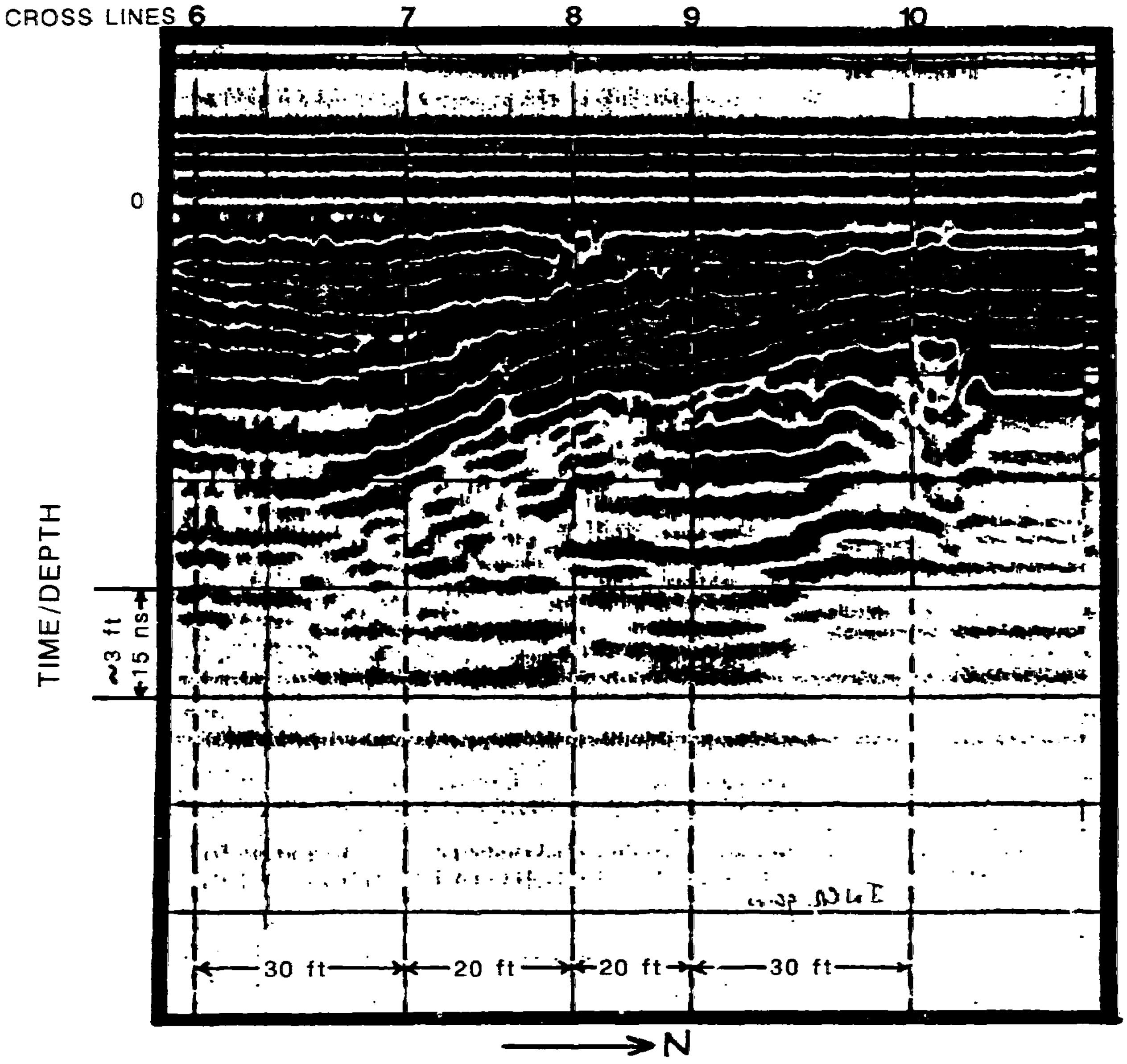


Figure 13. GPR sinkhole survey line 5.

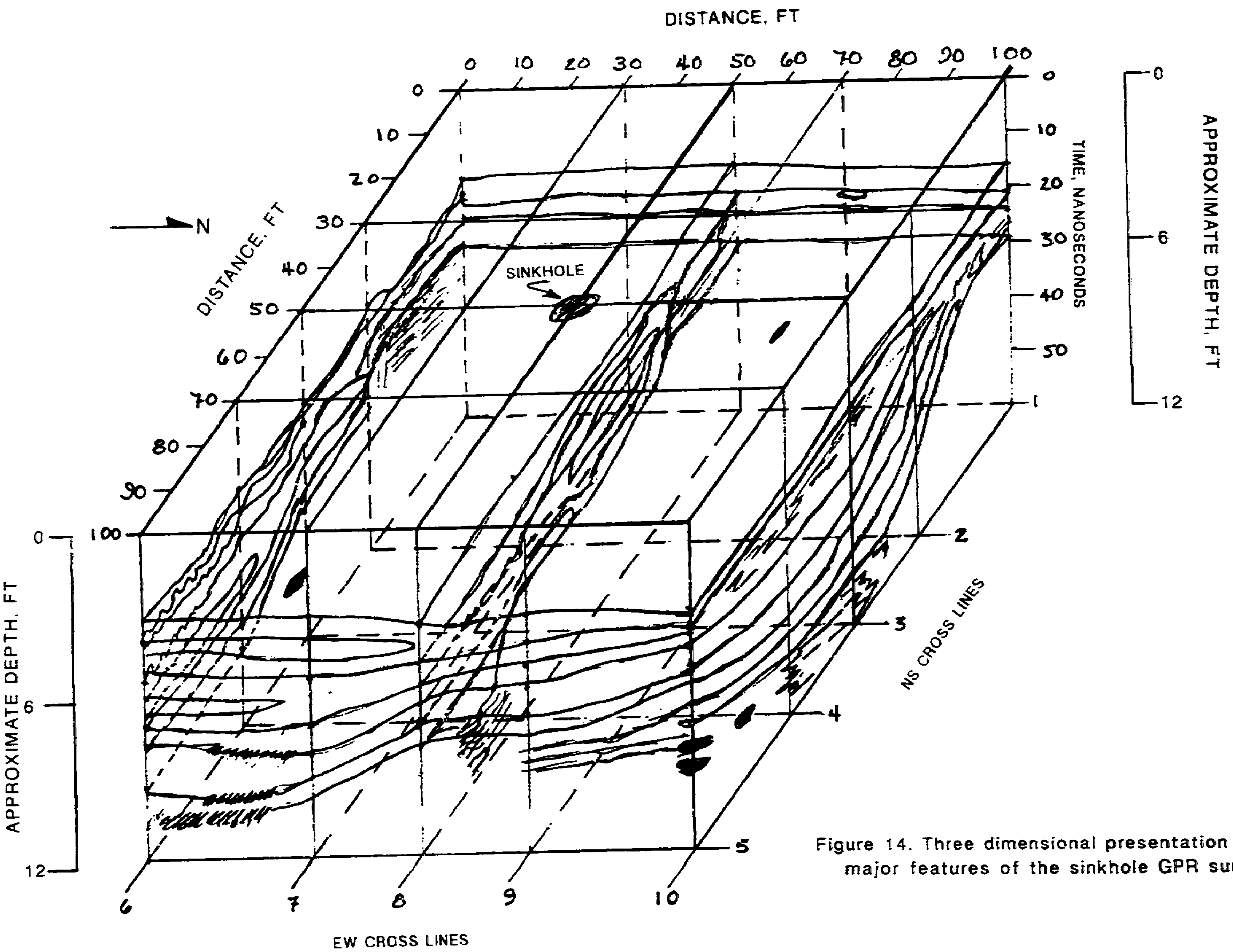


Figure 14. Three dimensional presentation of the major features of the sinkhole GPR surveys.

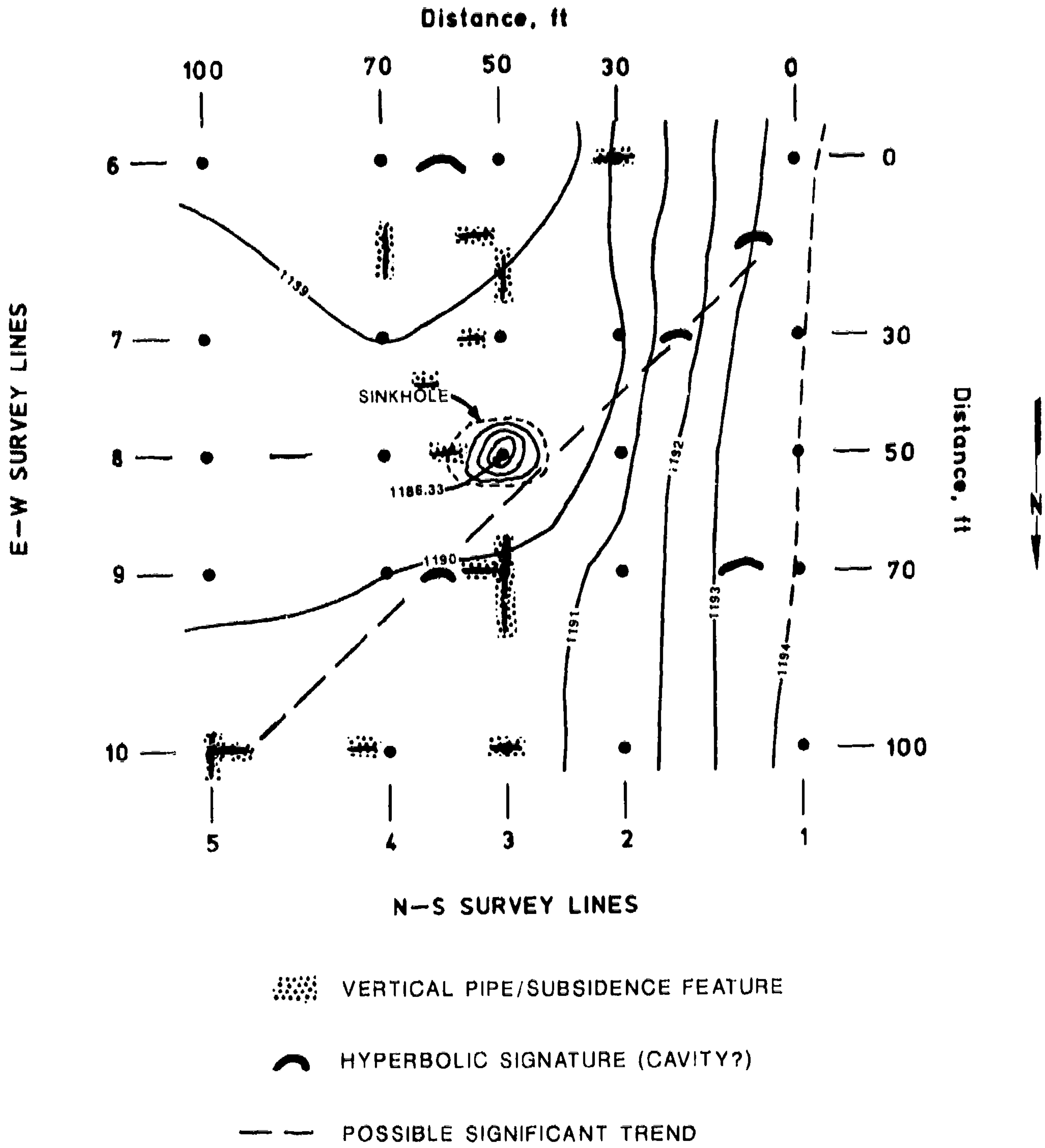


Figure 15. Map of localized anomalous features from sinkhole GPR surveys.

the reflecting basement in the sinkhole GPR surveys which lies 5-10 ft below the surface (nominal surface elevation -- 1190 ft) is likely the conglomerate. Two types of anomalous features are located in Figure 15, hyperbolic radar signatures (possible cavities) and signatures of possible vertical pipes/collapse features discussed above for lines 5 and 10. There are two alignments of anomalies which may be significant: (1) an alignment of features between the N-S survey lines 3 and 4, which includes the existing sinkhole; (2) a possible trend of anomalies from NE to SW, indicated by the dashed line in Figure 15.

Electromagnetic Conductivity

31. EM surveys were conducted along lines C,E, and F. Results of the EM surveys are given in Figures 16-21; the first of the two figures for each line includes the three HD profiles, while the second includes the three VD profiles. For line C, high conductivity anomalies exist at each end of the line, with nearly constant/uniform conditions vertically and horizontally in the central portion of the line. The anomalies at each end of line C extend beyond the limits of the survey. Using the approximate depths of investigation of the EM method discussed in Paragraph 19, a cross section of the EM anomalies is shown in Figure 22. The dashed lines which are parallel to the surface indicate the approximate depth of investigation for the three vertical dipole coil spacings. Also shown in the cross section are the locations of the exploratory borings, which were conducted during and shortly after the geophysical field program, and the ends of the concrete cutoff wall and grout curtain. Within the large anomalous areas C1 and C2, conductivities are in excess of 100 mmhos/m (10 ohm-m resistivity). Outside the anomalous areas, the conductivity is 15-20 mmhos/m (50-65 ohm-m resistivity), with minor anomalies as high as 30 mmhos/m (33 ohm-m resistivity). The C1 and C2 anomalies are most likely due to high water content, although high clay content is also a possibility.

32. The exploratory borings encounter gravel and cobbles, which is interpreted to be the conglomerate, at a nearly constant elevation along the survey line. Above the conglomerate, the borings encounter silt, which varies from dry to moist, and caliche, which varies from scattered small nodules to zones several inches thick. Borings U-5 and U-10 were anomalous in that U-5 encountered wet conditions at the top of the conglomerate and U-10 encountered 6 ft of wet silt above the conglomerate. Borings U-9 and U-10 were placed to investigate anomaly C2. The wet zone in U-10 supports the interpretation of a high water content explanation for anomalies C1 and C2.

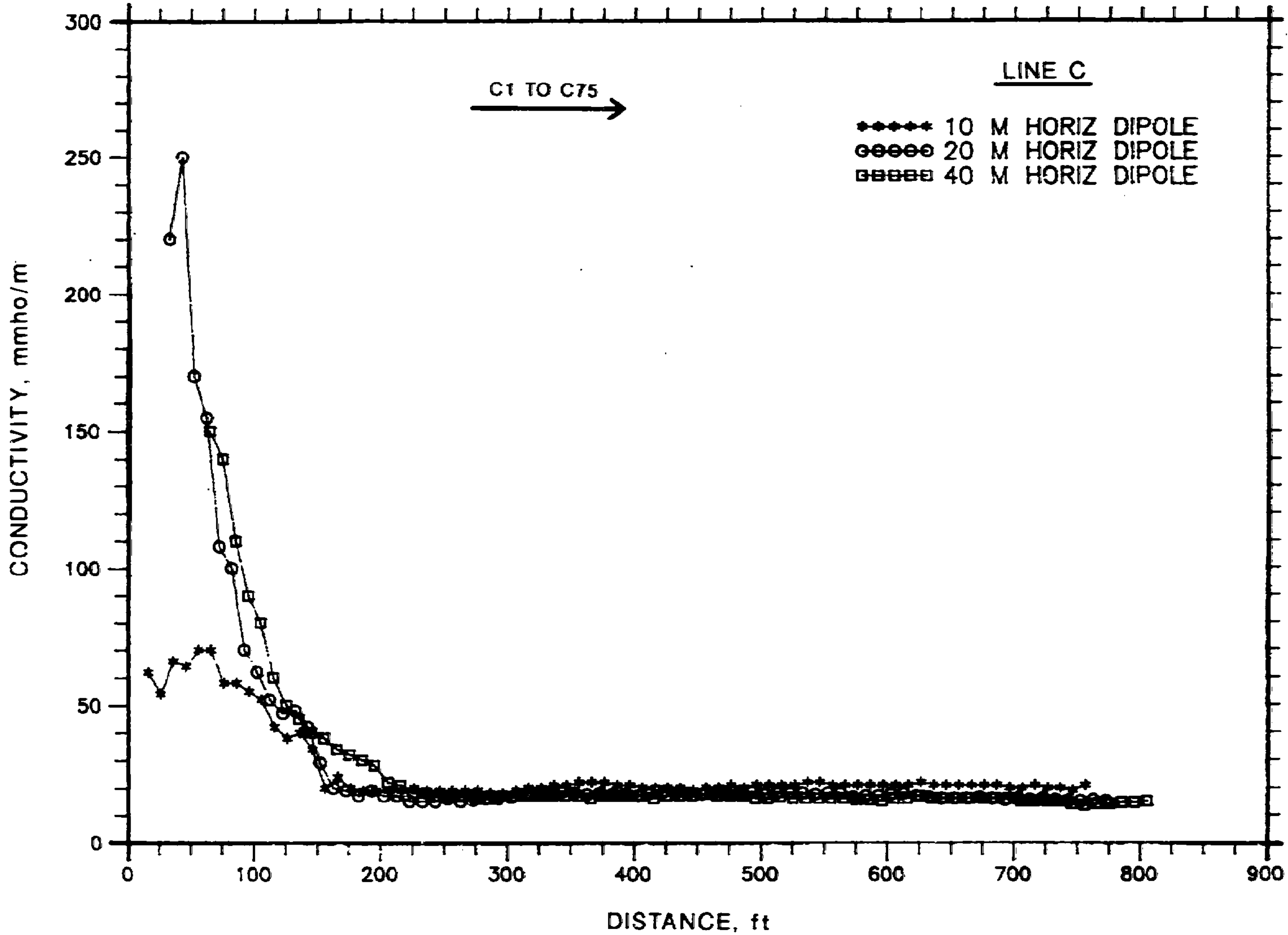


Figure 16. EM conductivity profiles, line C, horizontal dipoles.

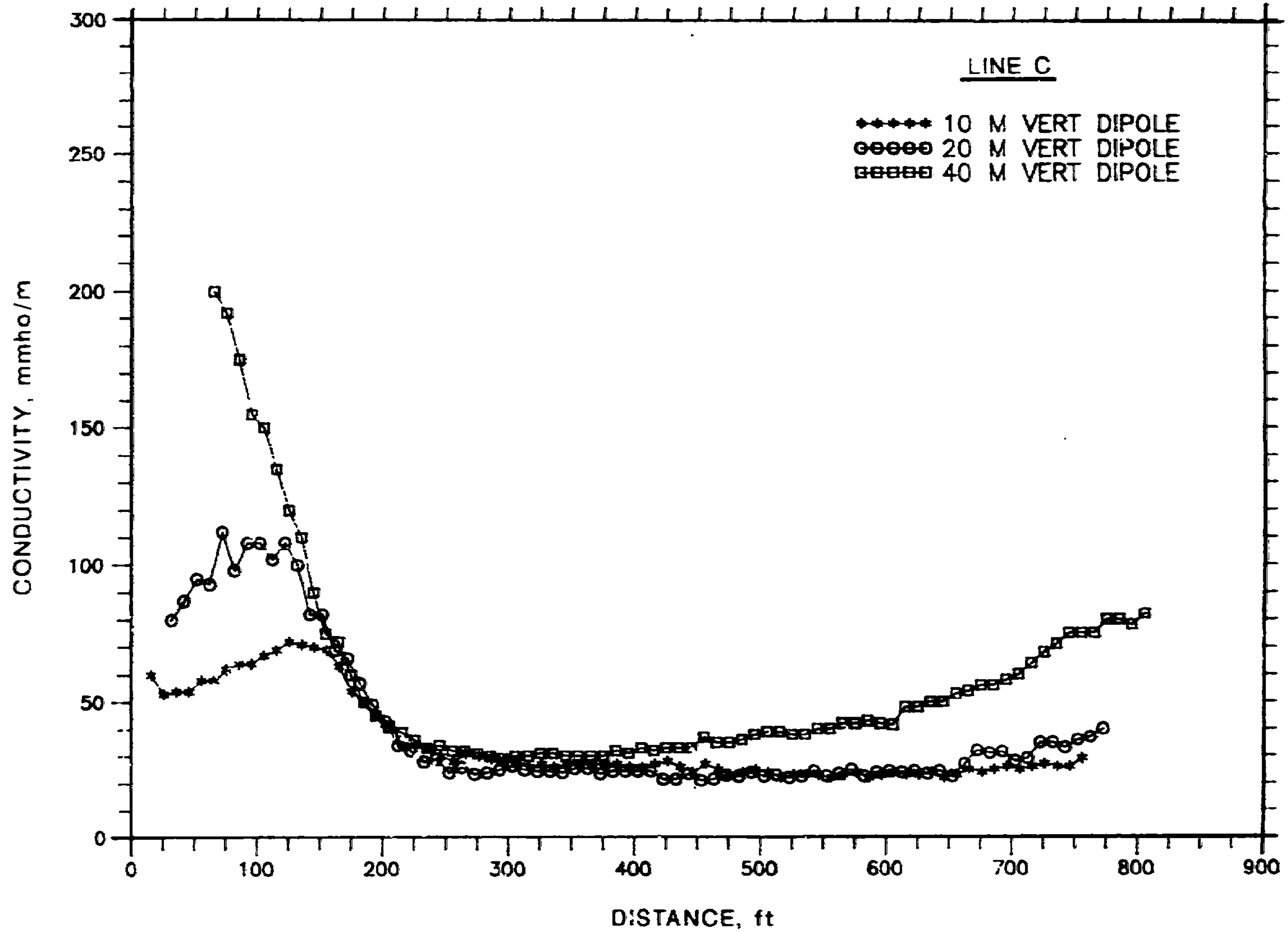


Figure 17. EM conductivity profiles, line C, vertical dipoles.

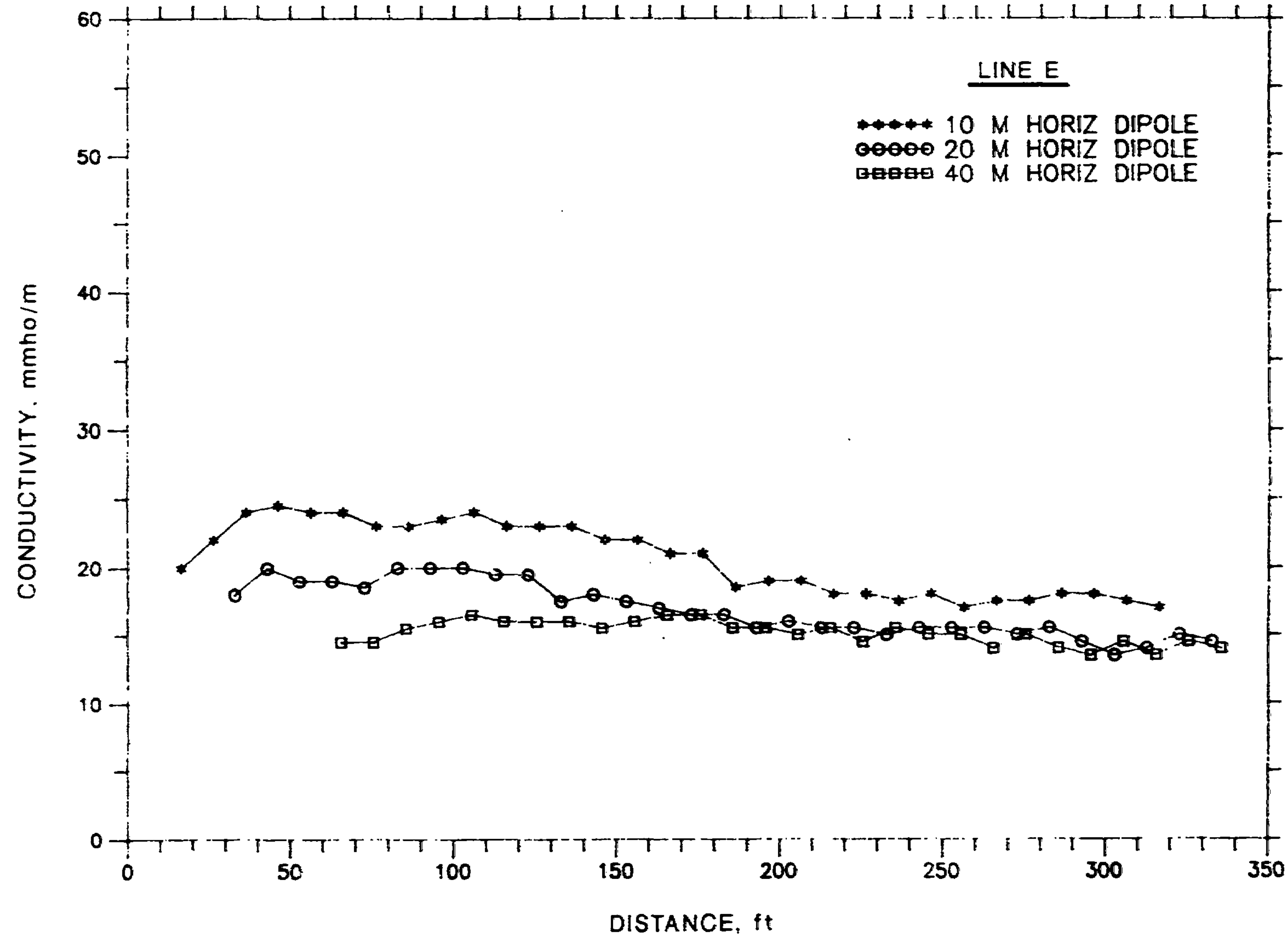


Figure 18. EM conductivity profiles, line E, horizontal dipoles.

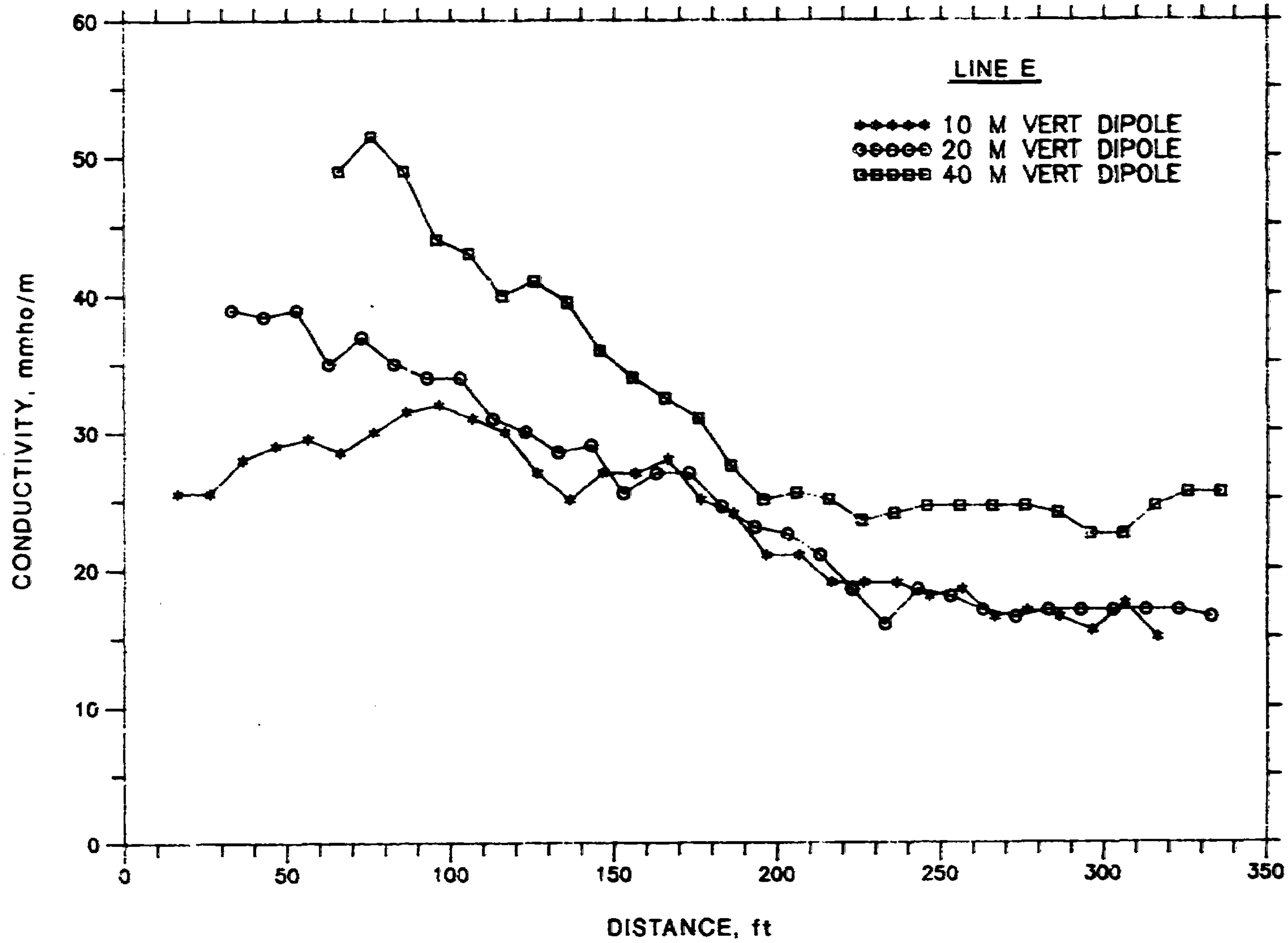


Figure 19. EM conductivity profiles, line E, vertical dipoles.

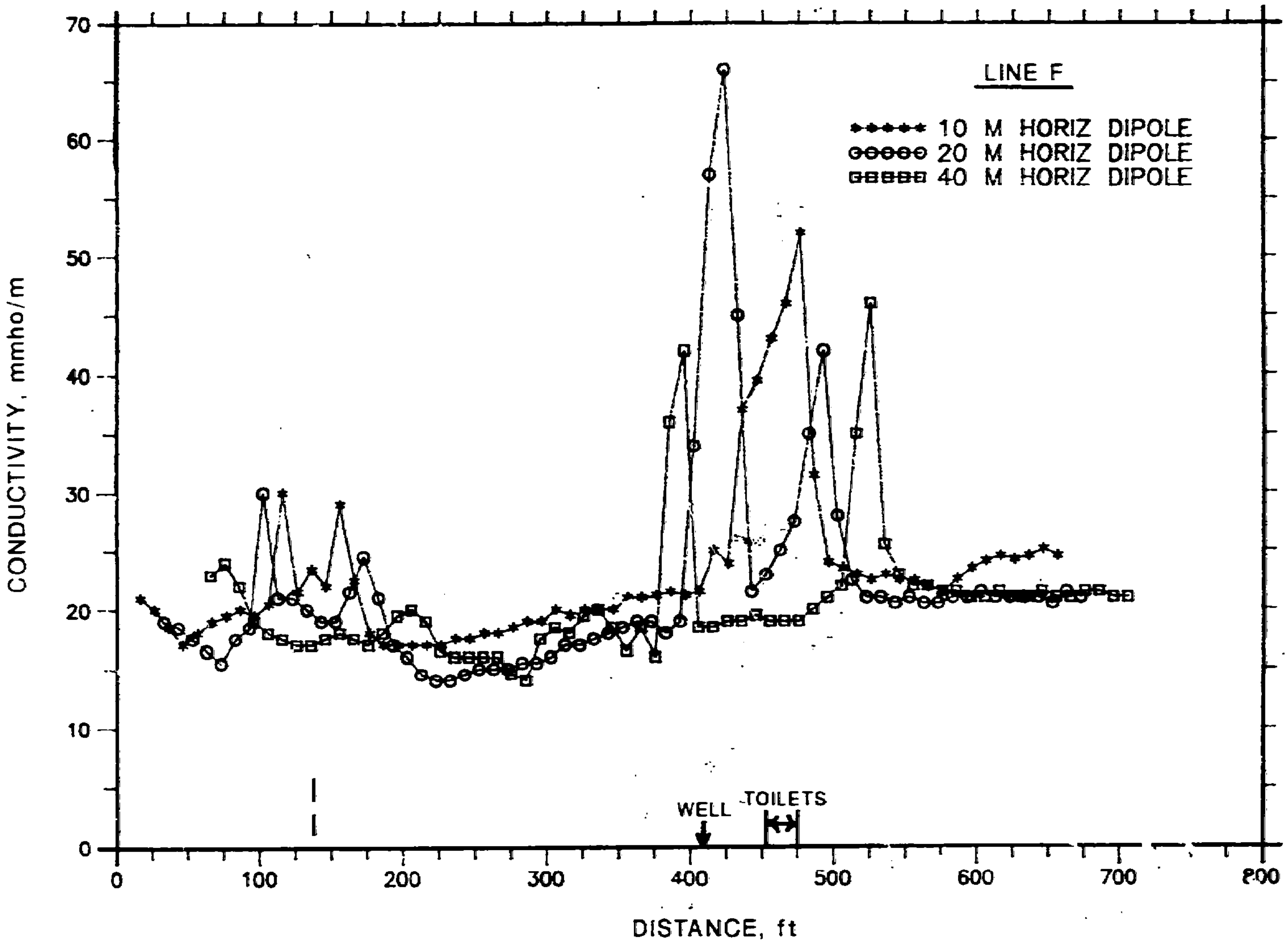


Figure 20. EM conductivity profiles, line F, horizontala dipoles.

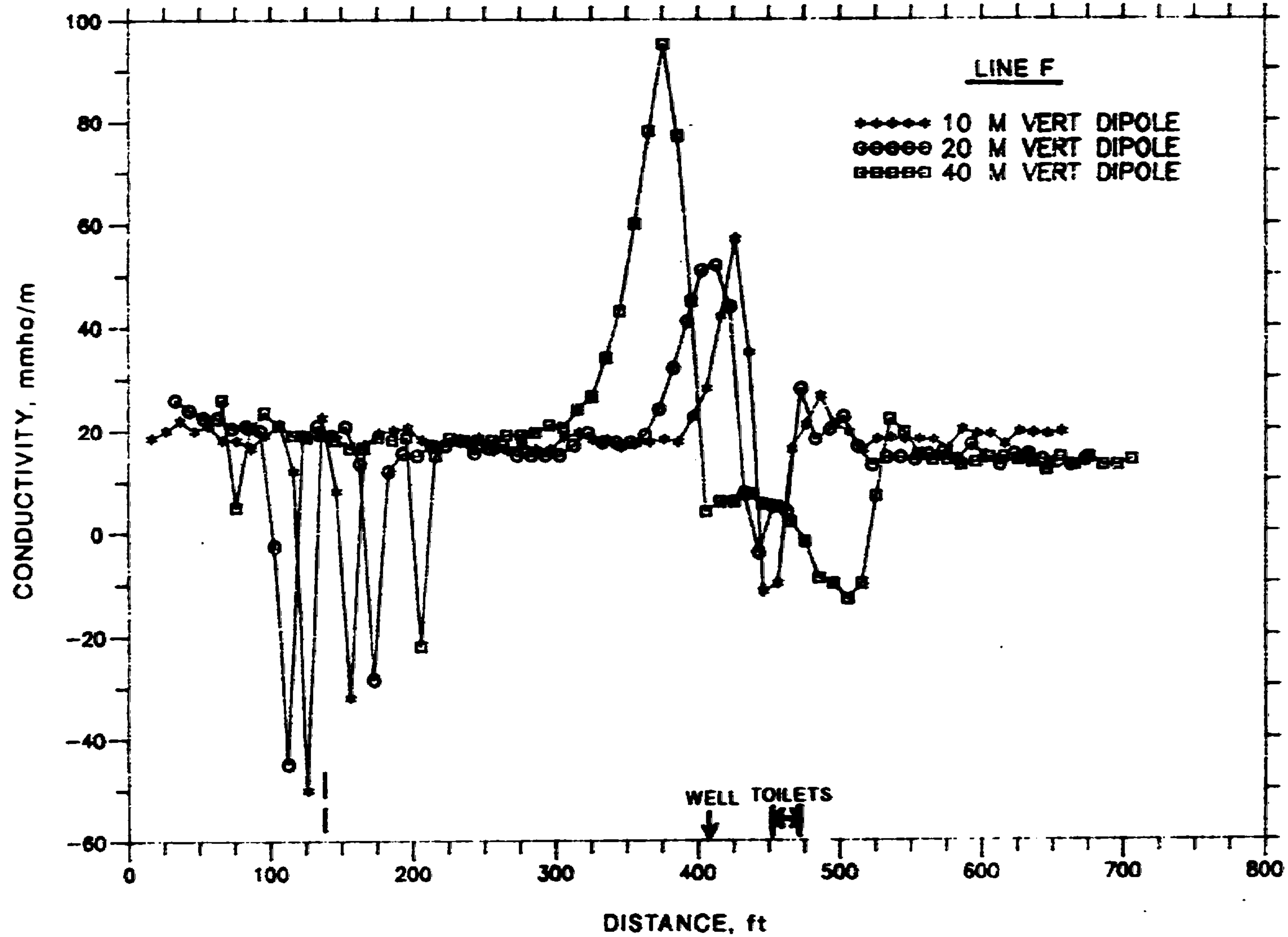


Figure 21. EM conductivity profiles, line F, vertical dipoles.

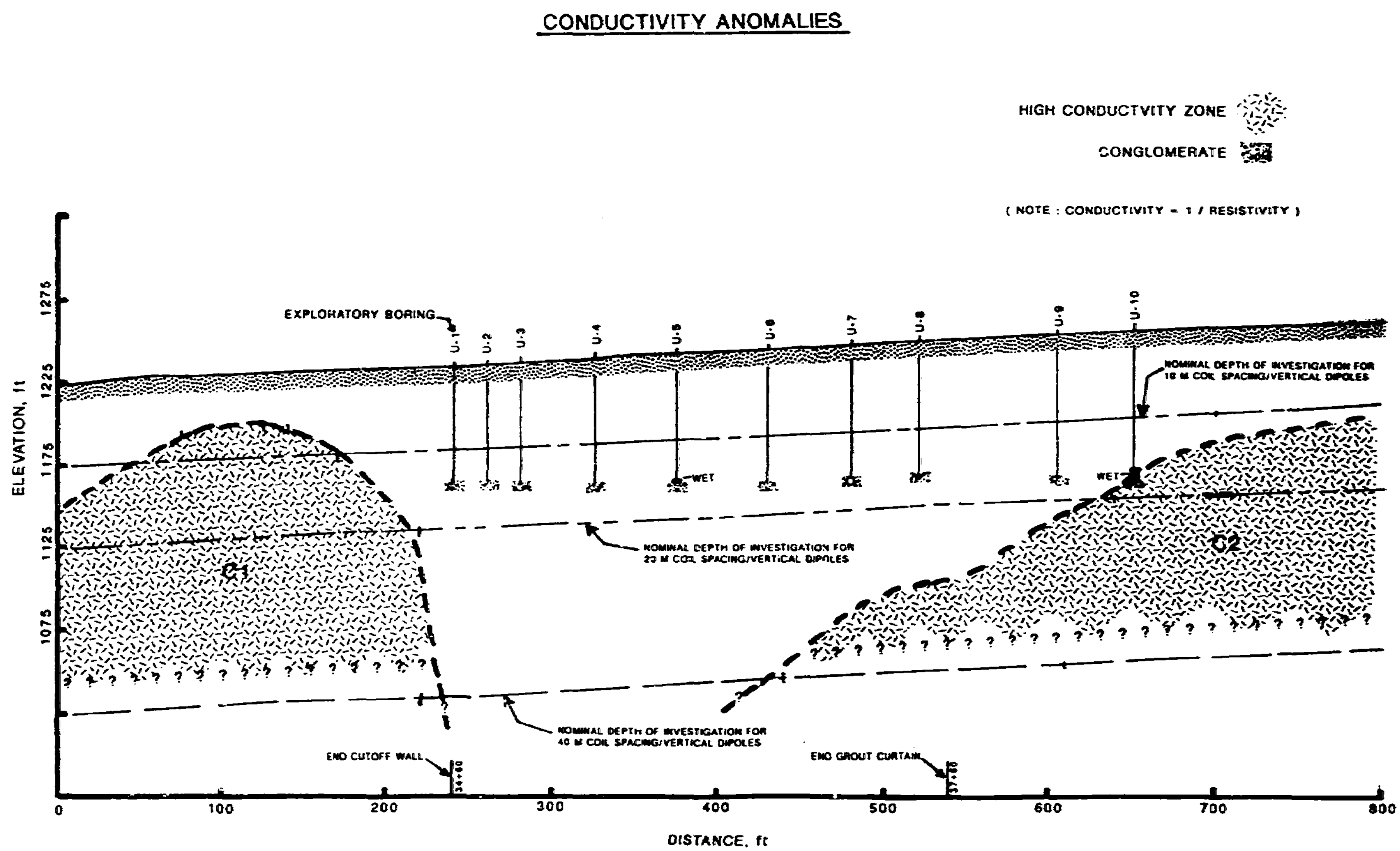


Figure 22. EM anomaly cross section, line C.

33. For line E, a high conductivity anomaly is indicated from the beginning of the line to approximately the 220 ft position. Beyond this anomaly, the conductivity, except for the 40 m VD data, is approximately the same as in the central region of line C. The 40 m vertical dipole data in the 220-350 ft region is elevated by nearly 50 percent relative to the rest of the EM data, which could indicate higher water contents at depths greater than about 100 ft.

34. The EM data for line F, Figures 20 and 21 is highly disturbed by cultural features: existing toilet facilities at location 450-475 ft; a deep well with metal casing at location 410 ft; an unmarked, buried cultural feature at location 130 ft (possibly a pipe associated with previous toilet facilities near this location). Along the segments of the survey line away from the cultural feature influence, the conductivity is uniform and approximately equal to the background levels for lines C and E. A shallow anomalous feature (<20 ft depth) exists at the right end of the survey line (location 600-700 ft), and a deeper anomalous feature is indicated at the left end of the line (location 0-100 ft). Plan locations of all the major EM anomalies are indicated on Figure 23.

Electrical Resistivity

33. Data from the individual soundings for the pole-dipole resistivity survey along line C are presented in Appendix C. The first set of sounding plots in the appendix are 'raw' apparent resistivity values plotted at the midpoint of the potential electrode pair locations, while the second set of data results from a center-weighted, three point moving filter applied to the raw data to produce smoothed sounding curves. Anomalies are identified relative to the smoothed curves. Using the graphical interpretation procedure discussed in Paragraph 21, the resistivity anomaly cross section shown in Figure 24 results. It is highly significant that anomalies R1 and R2 correlate both in sense (high/low) and location to the EM conductivity anomalies C1 and C2. The small, low resistivity anomaly R3 is apparently confirmed by boring U-5, which encountered wet conditions at the top of the conglomerate. Of anomalies R3-R7, only R5 is possibly expressed in the EM conductivity data. The high resistivity anomalies are likely caused by dryer conditions in the silt and/or zones with higher caliche concentration. The EM method does not have the vertical resolution of the pole-dipole method and it is likely that the high resistivity anomalies are masked in the EM data by the large response to anomalies C1 and C2.

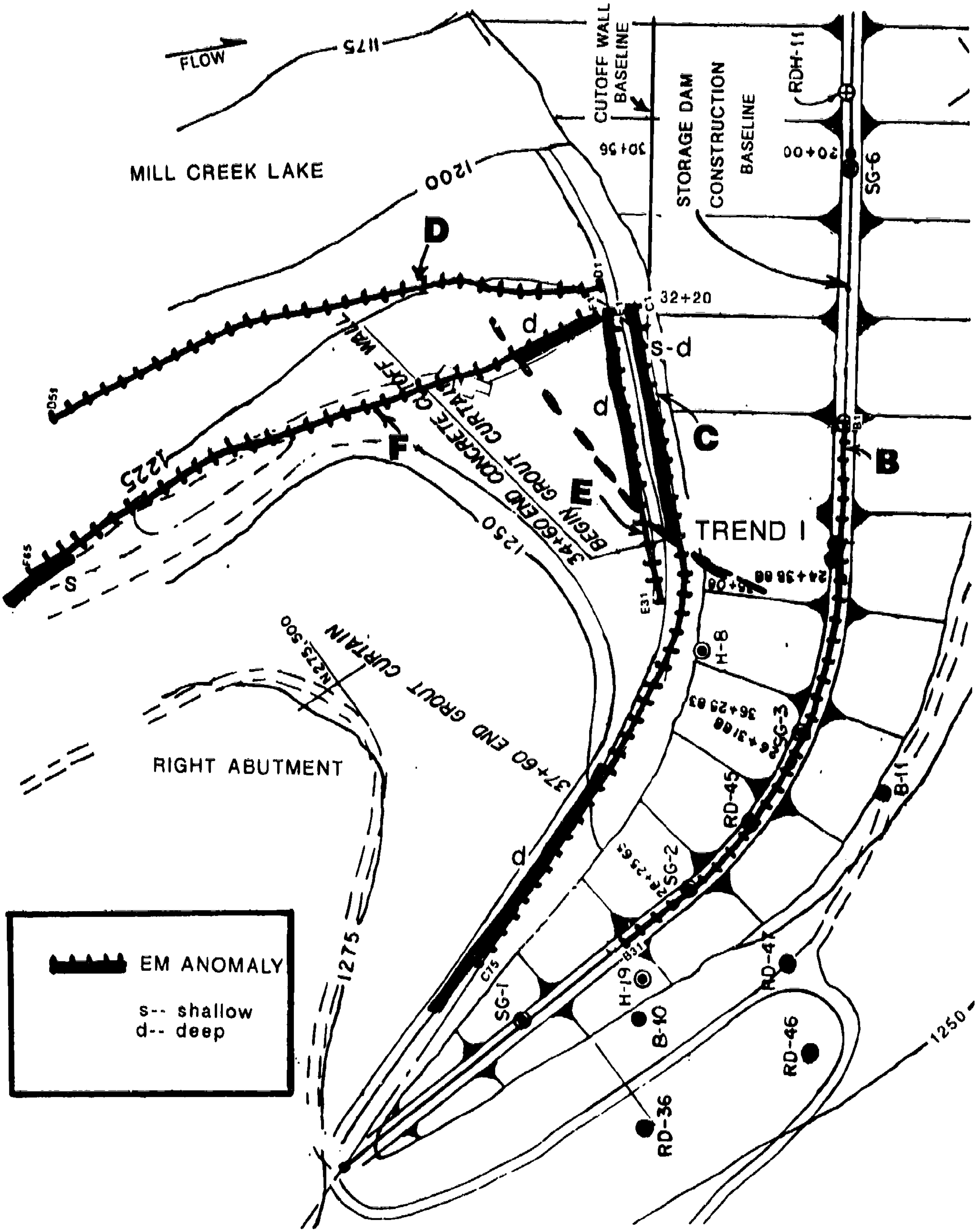


Figure 23. EM anomaly locations.

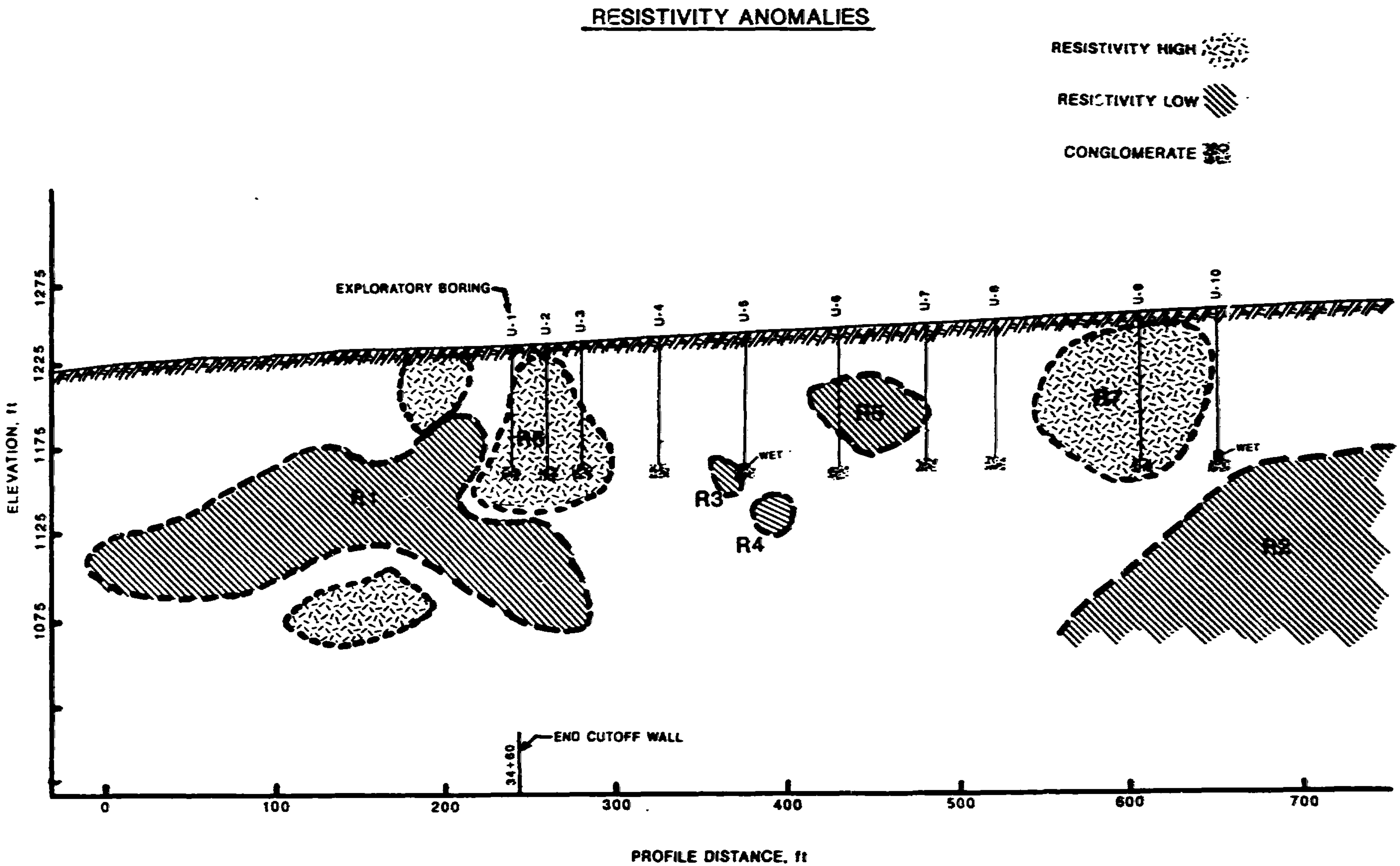


Figure 24. Resistivity anomaly cross section, line C.

Microgravity

34. The Bouguer gravity results for lines B-F are shown in Figures 25-29 respectively. The results are relative to the base station for line C (C37 or 360 ft); i.e., the data for each line are corrected to the latitude and elevation for C37, the reference gravity value for C37 is subtracted from all the data, and then the data are terrain corrected. Reference or 'best fit' curves through the data are given for each line. The data are scattered relative to these curves, representing actual anomalies caused by small, shallow subsurface features (typically less than 20 ft or 6 m deep), data measurement errors, and in many cases errors due to incomplete terrain correction. Incomplete terrain corrections in this case refers to incomplete definition of terrain variations close to each measurement location, say within a 10 ft (3 m) radius. Incomplete terrain correction errors will affect the data for lines C and D more than for lines B, E, and F. The complete set of measured and processed gravity data is included in Appendix D in the form of computer printouts.

35. The anomalies caused by the curves in Figures 25-29 are caused by large scale and/or deep-seated features (relative to the small anomalies discussed above). The old addage, that anomalies inevitably occur near the ends of survey lines, is dramatically illustrated by the gravity data for lines B, C, and E, where low gravity anomalies occur near the ends of the lines. Low gravity anomalies also appear in the data for lines D and F, but these lows are more completely defined. Figure 30 is a plan map showing the spatial extent of the low gravity anomalies. The center of the anomaly can be defined for lines D and F and for one of the anomalies on line C. These anomaly centers are indicated on Figure 30; and the double dashed line indicates a significant alignment of low gravity anomalies (Trend II), possibly caused by a low density anomalous feature extending through the right abutment and passing underneath the dam. Another possible alignment of low gravity anomalies is indicated in Figure 30 near the right ends of lines B, C, and E (Trend I), also apparently caused by a feature extending underneath the dam.

36. The low gravity anomalies, for which centers were indicated above, are complete enough for depth estimates to be made. Depth estimates are made for a particular assumption of feature geometry. The anomalous feature is assumed to be elongated, with a compact, constant cross sectional area and to have a sub-horizontal orientation, e.g., a long, nearly horizontal circular cylinder. Using this assumption, the following depth estimates (to center of the anomalous feature) result:

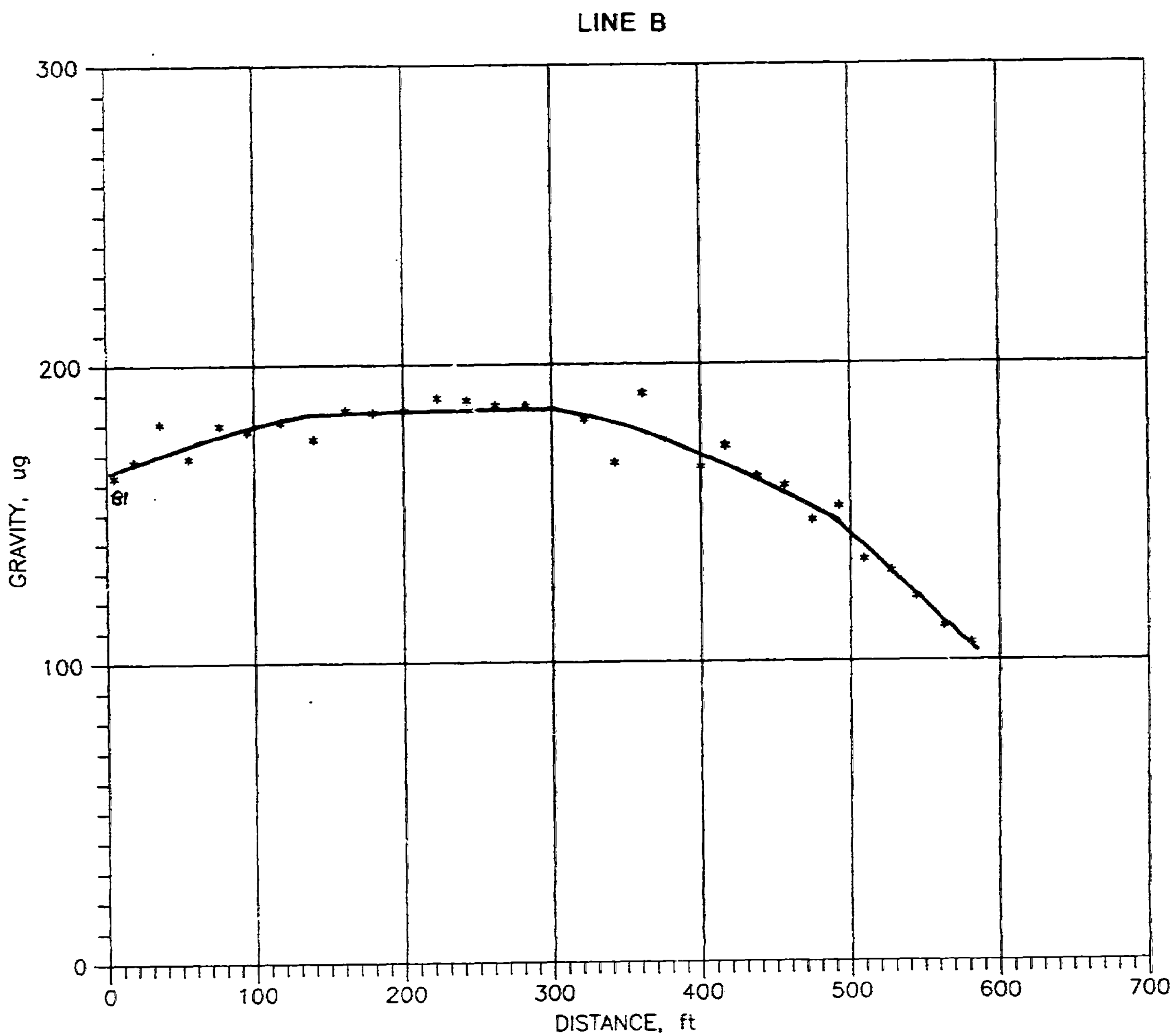


Figure 25. Terrain corrected Bouguer gravity profile. line B.

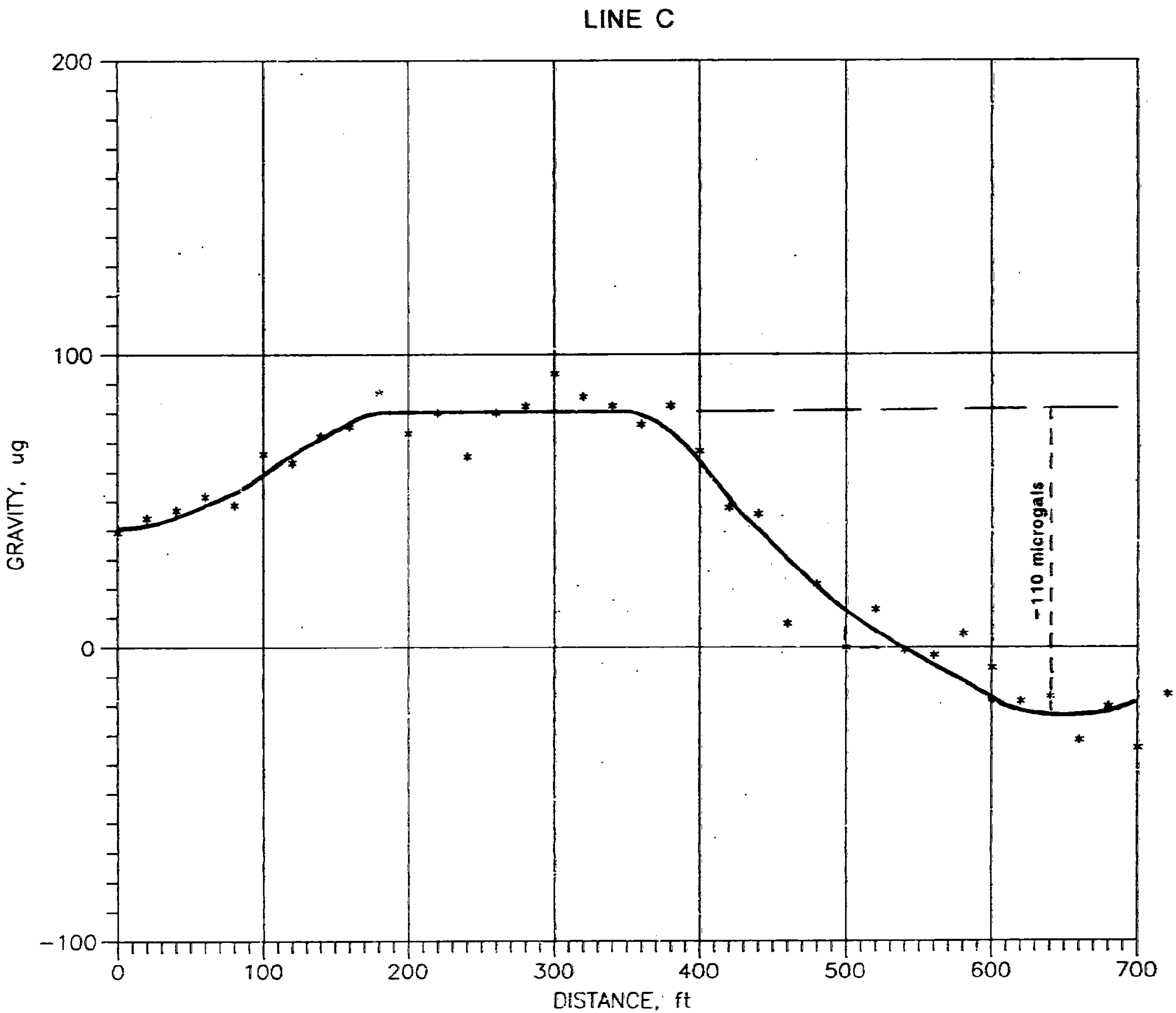


Figure 26. Terrain corrected Bouguer gravity profile. line C

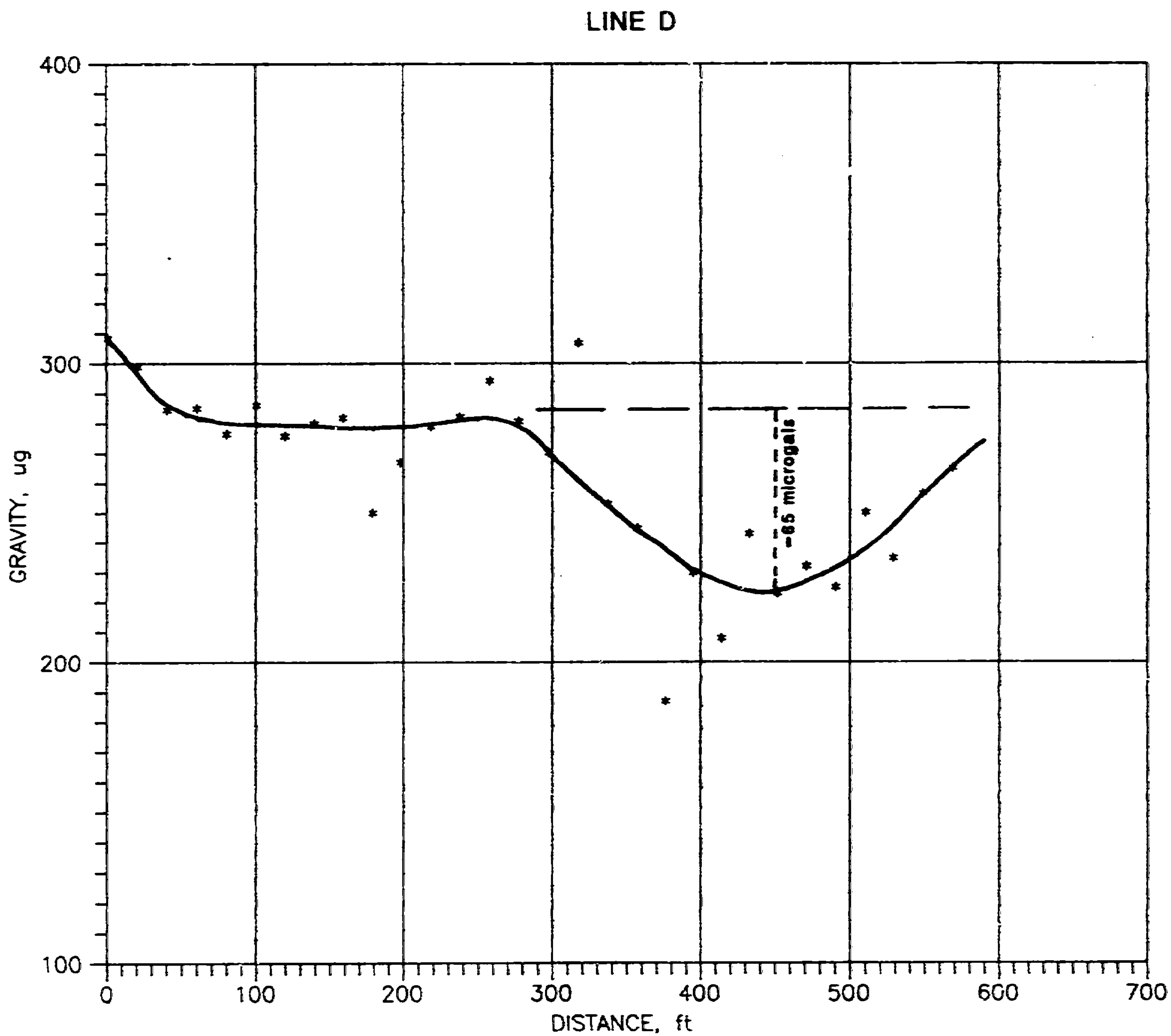


Figure 27. Terrain corrected Bouguer gravity profile, line D

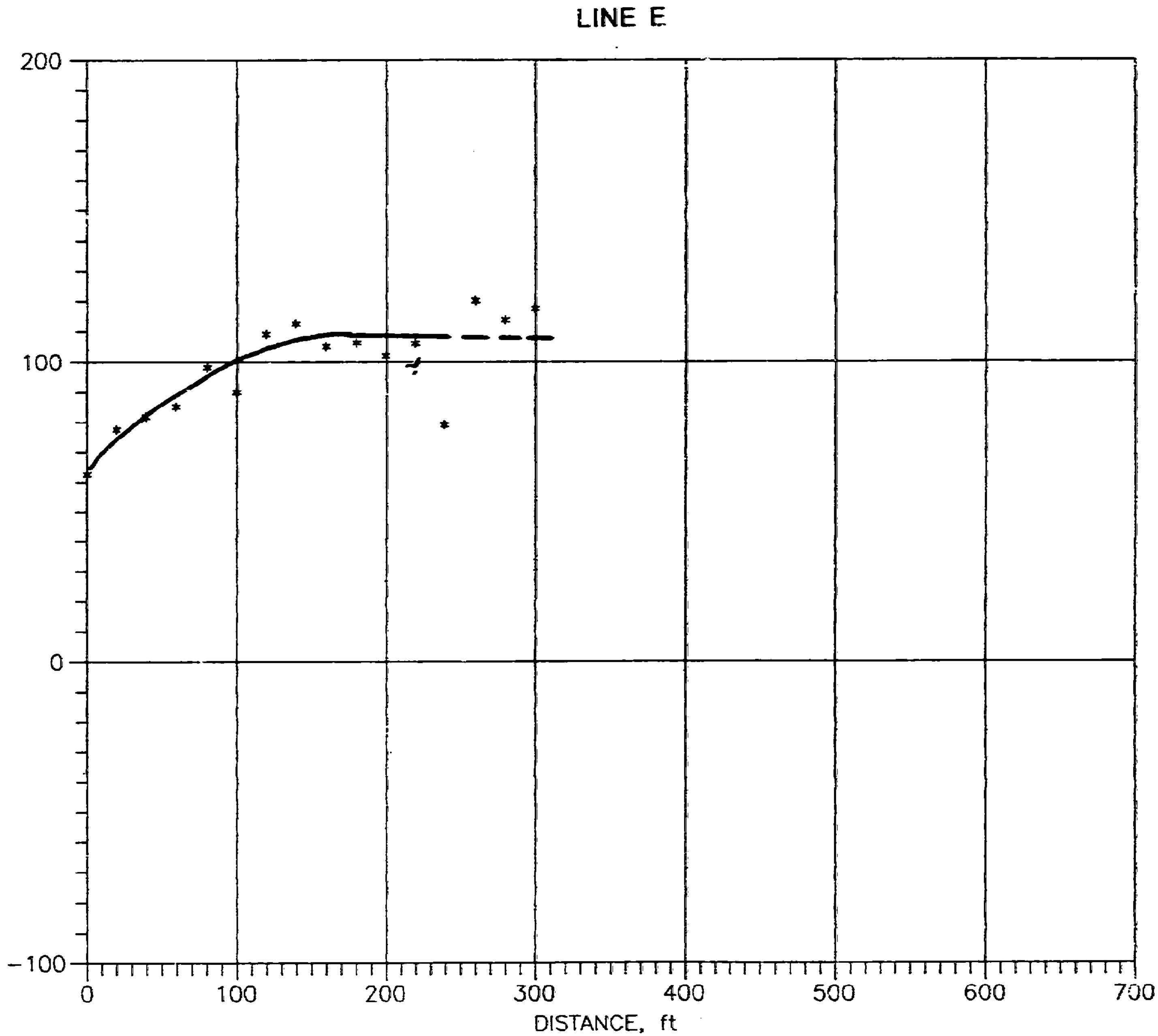


Figure 28. Terrain corrected Bouguer gravity profile, line E

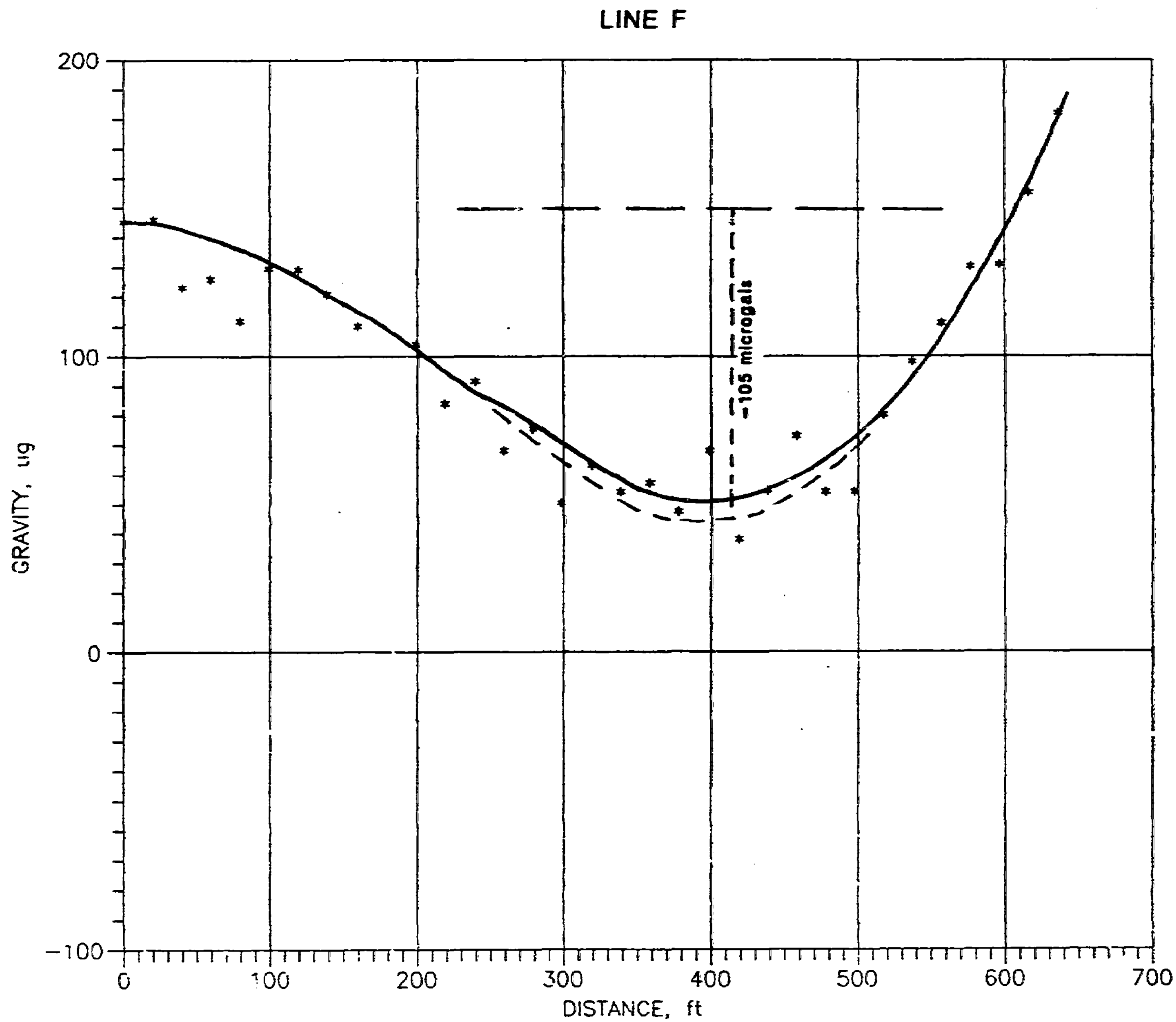


Figure 29. Terrain corrected Bouguer gravity profile, line F

Line	Anomaly Center	Anomaly Magnitude (microgals)	Depth (ft)
C	C71 (700 ft)	- 110	190
F	F43 (420 ft)	- 105	140
D	D47 (460 ft)	- 65	100

The depth estimates are arranged according to decreasing depth. Since the anomaly magnitude apparently increases with increasing depth, the anomalous feature must be larger in physical size and/or density contrast as it passes successively under lines D, F, C and B.

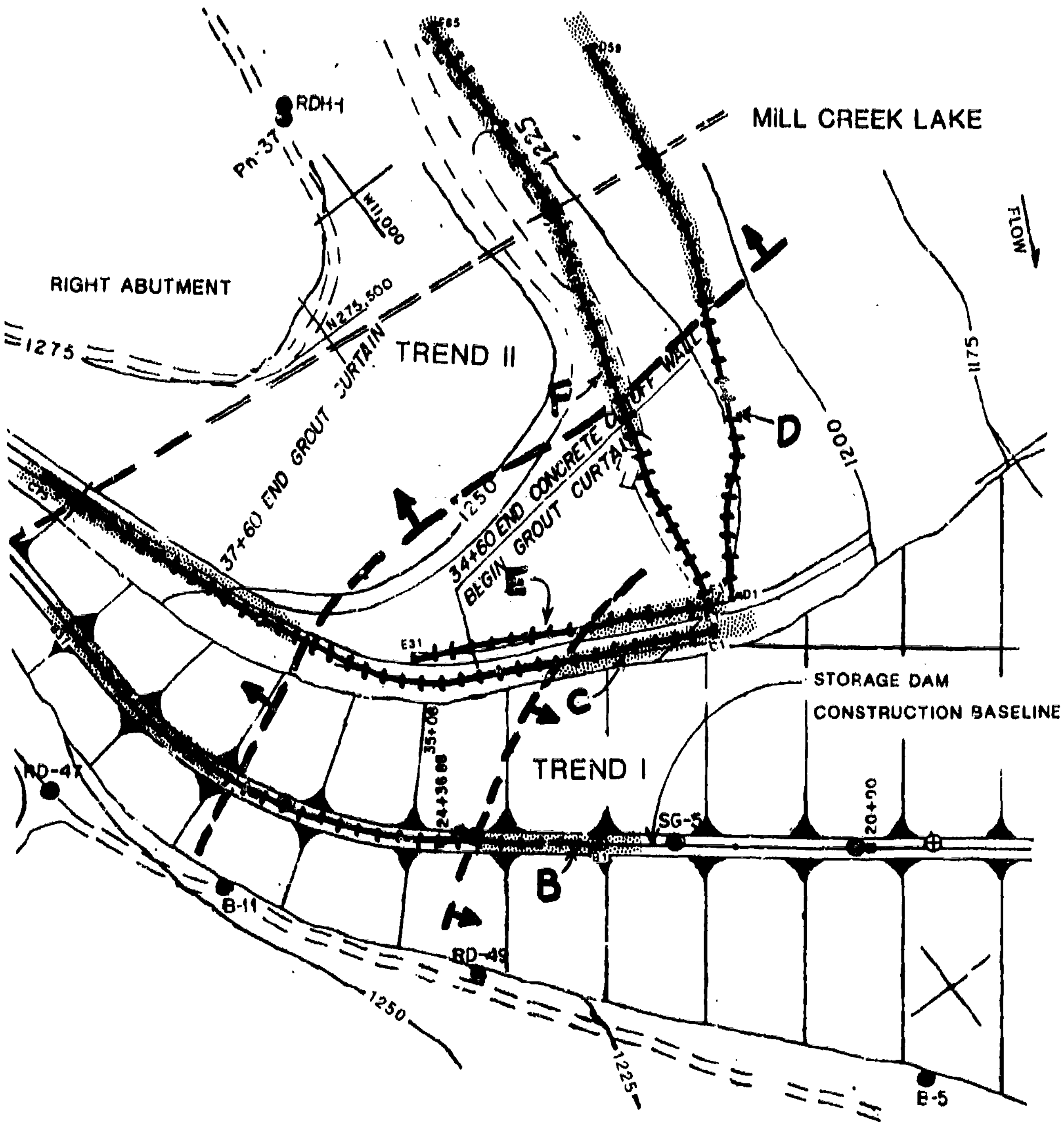
37. The above interpretation based on the simple assumption of a model geometry is not unique. First, for the computed depth, in each case only the product of density contrast and mean radius can be computed (Butler 1980), where density contrast refers to the difference between the density of the anomalous feature and the density of the surrounding material. The following tabulations are calculations of the mean radius of the anomalous feature for selected density contrasts for two of the cases presented above:

Line C -- Depth to Center = 190 ft (58 m)

Density Contrast g/cm^3	Mean Radius ft (m)
- 0.1	130 (40)
- 0.2	90 (27)
- 0.3	74 (23)
- 0.4	64 (20)
- 0.5	57 (17)
- 2.2	27 (8)

Line D -- Depth to Center = 100 ft (30 m)

Density Contrast g/cm^3	Mean Radius ft (m)
- 0.1	71 (22)
- 0.2	50 (15)
- 0.3	41 (13)
- 0.4	36 (11)
- 0.5	32 (10)
- 2.2	15 (5)



CENTER OF LOW GRAVITY ANOMALY

LOW GRAVITY REGION

POSSIBLE ALIGNMENT OF LOW GRAVITY ANOMALIES

LOW GRAVITY REGION

Figure 30. Synopsis of gravity results--low gravity anomalies.

The $-2.2\ g/cm^3$ density contrast is included as an extreme case, representing an air-filled cavity in the conglomerate; a water-filled cavity would have a density contrast of $-1.2\ g/cm^3$. A more likely density contrast of uncemented relative to cemented conglomerate or a zone in which piping has occurred is -0.2 to $-0.3\ g/cm^3$. A second way in which the interpretation may not be unique is that the assumption of feature geometry may be invalid. Other assumptions of geometry will result in shallower depths (Butler 1980).

38. A Bouguer anomaly contour map for the sinkhole microgravity survey is shown in Figure 31, where the circled numbers correspond to the GPR survey lines. An anomaly caused by the small existing sinkhole does not appear on the gravity map due to insufficient gravity measurements in the immediate vicinity of the sinkhole. A three dimensional representation of the Bouguer anomaly data is presented in Figure 32 from the same perspective as the GPR fence diagram in Figure 14. The gravity data surface has the same trend as the major GPR reflector, an overall dip to the SE (low gravity anomaly to the SE). The low gravity trend to the SE supports the suggestion that the major GPR reflector dipping to the SE is the conglomerate, since the conglomerate should represent a positive density contrast relative to the silt. A localized low gravity anomaly near location (30,30) is well defined and correlates well in location with a hyperbolic GPR feature (cavity) and the NE-SW significant GPR anomaly trend noted earlier.

Integrated Assessment

39. An integrated, complementary geophysical program was conducted at the site, however the results of the individual methods varied greatly in their applicability and contribution to the program. The shallow, seismic reflection method was least successful at the site and contributed least to the program. Lack of identifiable silt/conglomerate reflections in the results of the seismic tests likely indicates that the conglomerate is uncemented in the three locations, which is consistent with the gravity survey results which have low gravity (low density) anomalies in the three locations.

40. The GPR has a maximum effective depth of investigation at the site of approximately 30 ft. GPR records along the toe of the dam and on the right abutment are relatively featureless, i.e., the records indicate relative uniform conditions laterally and vertically to a depth of 30 ft. In contrast, the GPR results in the vicinity of the sinkhole in the floor of the reservoir were remarkable in the amount of detail exhibited in the records. The sinkhole GPR records indicate a prominent reflector dipping to the SE and isolated vertical pipe features and possible

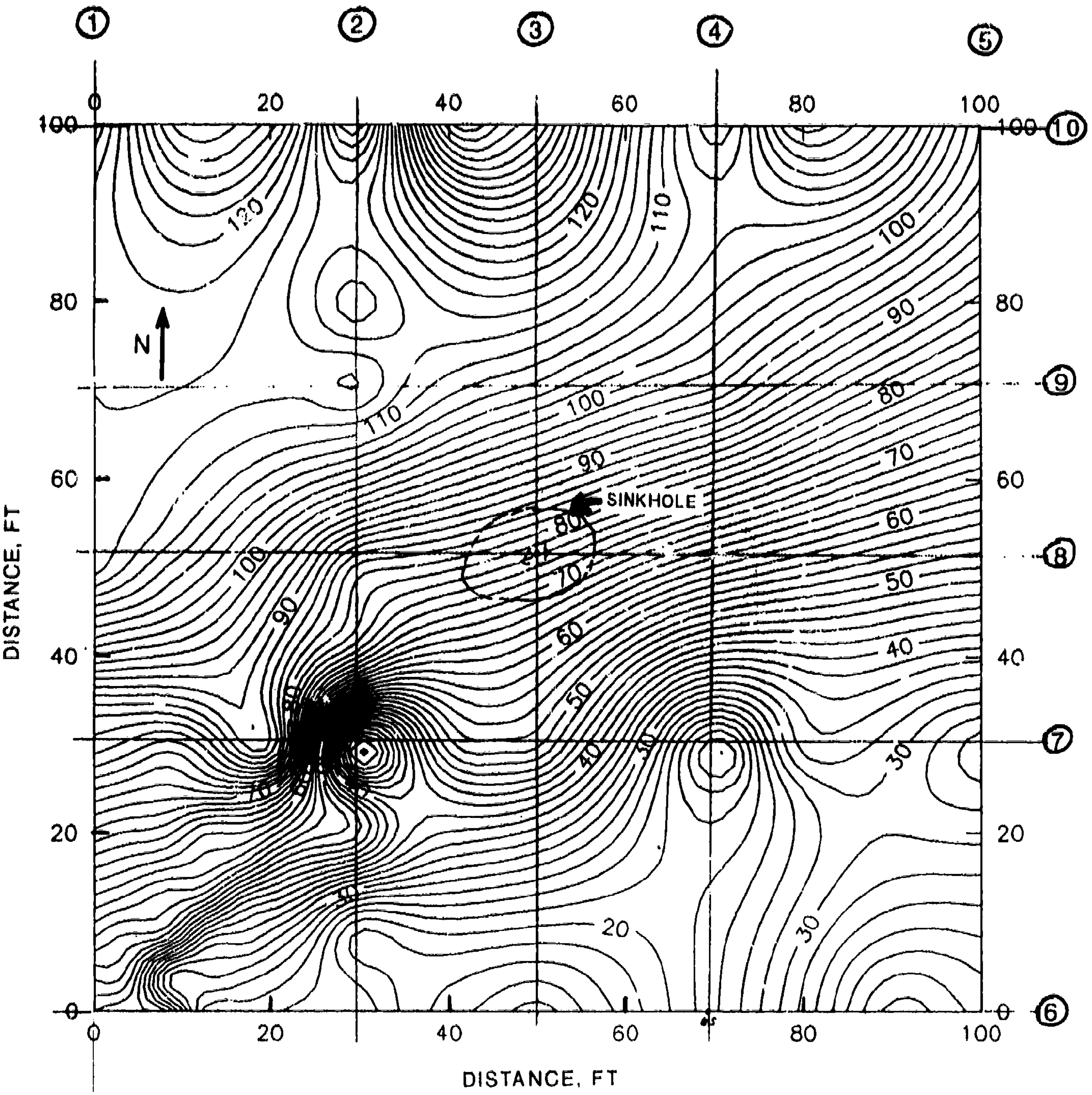


Figure 31. Gravity map of sinkhole area; contours in miciogals.

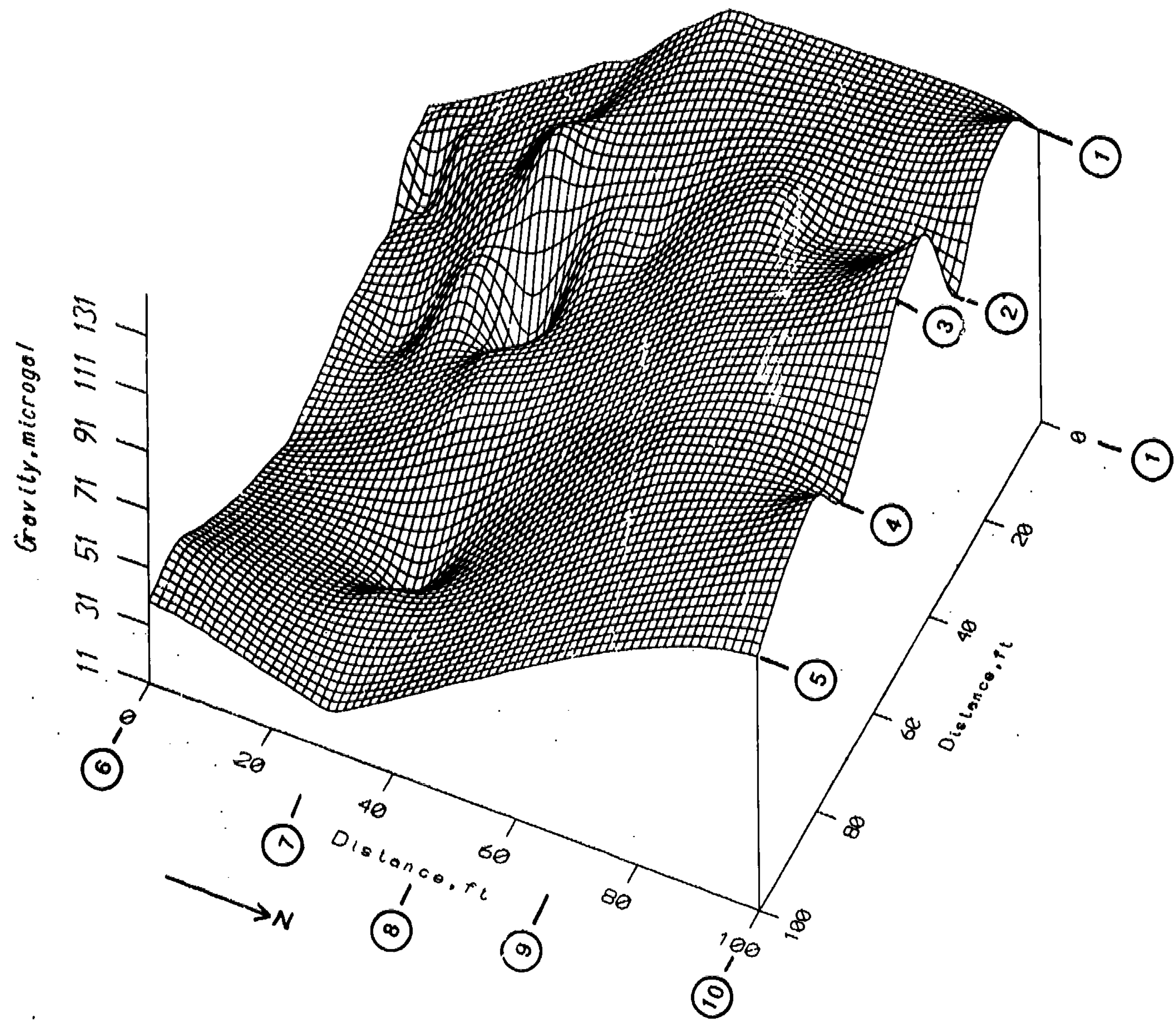


Figure 32. Three-dimensional representation of gravity data around sinkhole. Circled numbers refer to the GPR survey lines.

cavities (Figures 14 and 15). The silt/conglomerate interface is a viable candidate for the reflector in the vicinity of the sinkhole. The results and interpretation of the sinkhole GPR surveys and consistent with the sinkhole microgravity survey results and interpretation (Figure 32).

41. Along the upstream toe of the dam in the right abutment area, line C, results and interpretations of the electromagnetic conductivity, electrical resistivity, and microgravity surveys are quite consistent. All three methods indicate anomalous conditions at each end of line C. The subsurface features causing the anomalies are interpreted as low density, high water content zones. The EM and ER interpretations indicate that the anomalous features extend from depths of 50-100 ft to depths of 150-200 ft or greater (Figures 22 and 24). One interpretation of the microgravity results, which assumes that the anomaly at the north end of line C is caused by a cylindrical cross-section feature, gives a depth to anomaly center of 190 ft and a mean anomaly radius of 74 ft (90 ft) for an assumed density contrast of - 0.3 g/cm^3 (- 0.2 g/cm^3). This microgravity interpretation is consistent with the EM and ER interpretations. The ER and EM interpretations are confirmed in two locations along line C by results of the exploratory drilling program.

42. The microgravity survey results and interpretations indicate two anomalous trends which apparently pass under the dam (Figure 30, Trends I and II). The southernmost trend, Trend I, is consistent with the possible trend indicated by EM anomalies shown in Figure 23.

43. The locations of the anomalous zones in relation to the right abutment terminations of the concrete cutoff wall and grout curtain is likely not coincidental, and strongly suggests that the cause of the anomalies is seepage related. A seepage-related cause for the anomalous zones is supported by the results of the self potential (SP) surveys and other geotechnical investigations conducted during the 1984 test fill of the reservoir (Butler, Wahl and Sharp 1984). Two long self potential survey lines were established which included the present lines C and F. For the SP line which paralled the dam centerline along the cutoff wall/grout curtain alignment (including the present line C), anomalous seepage was indicated near the dam/right abutment contact and termination of the cutoff wall. Along the SP line perpendicular to the dam (including the present line F), anomalous seepage was indicated very close to the center of the low gravity anomaly on line F.

PART IV : CONCLUSIONS AND RECOMMENDATIONS

Conclusions

43. An integrated, complementary geophysical program directed to the detection and delineation of anomalous conditions in the right abutment of Mill Creek Dam, Walla Walla, Washington, was planned and conducted. During and shortly after the geophysical field program, exploratory drilling was conducted along the upstream toe of the dam in the right abutment area. The following major conclusions result from the integrated assessment of the geophysical program and exploratory drilling:

a. Two anomalous trends apparently extend from the reservoir through the right abutment and under the dam; interpreted depths of the two anomalous feature trends place the features likely within the conglomerate; the interpreted features have low density and high water content; one of the anomalous trend interpretations is confirmed by an exploratory borehole which encountered a 5 ft wet zone in the silt just above the conglomerate;

b. Surveys around a small sinkhole in the reservoir floor reveal a conglomerate surface which dips to the S-SE; several vertical pipe features and small cavities are detected within the conglomerate, consistent with a scenario of vertical seepage and piping of silt into the conglomerate;

c. The shallow subsurface in the right abutment area to a depth of 30 ft is relatively uniform laterally; the exploratory drilling confirms the geophysical interpretation.

44. Examination of all the results, particularly along line C, suggests that the anomalous conditions and trends are controlled or at least strongly influenced by the cutoff wall and grout curtain. A seepage-related cause for the anomalous trends is strongly suggested by the present results and supported by results of self potential surveys and other geotechnical investigations conducted during the 1984 reservoir test fill.

Recommendations

45. The conclusions (1) that two low density, high water content anomalous zones pass through the right abutment and underneath the dam and (2) that these anomalous zones are caused by seepage related processes are interpretations, based on exten-

sive geophysical and geotechnical data, and are considered well founded. However, the interpretations were only marginally confirmed by direct sampling of material during the exploratory drilling program. If further exploratory/confirmatory drilling is undertaken, a minimum recommended program is presented in Figure 33, where the basis for the recommendation is indicated. The drilling program ideally should include sampling immediately above and within the conglomerate and holes should extend to the top of the basalt. Drilling in the conglomerate, however, will be difficult and expensive and the results possibly ambiguous due to the drilling and sampling difficulties. Selective, shallow drilling in the vicinity of the sinkhole to depths of at least 30 ft is recommended would be more easily achievable.

46. Depending on project fate decisions to be made by the District and Division, future geophysical investigations may be justified. Using the present geophysical data as a baseline, future surveys could detect changes in subsurface conditions in the right abutment area.

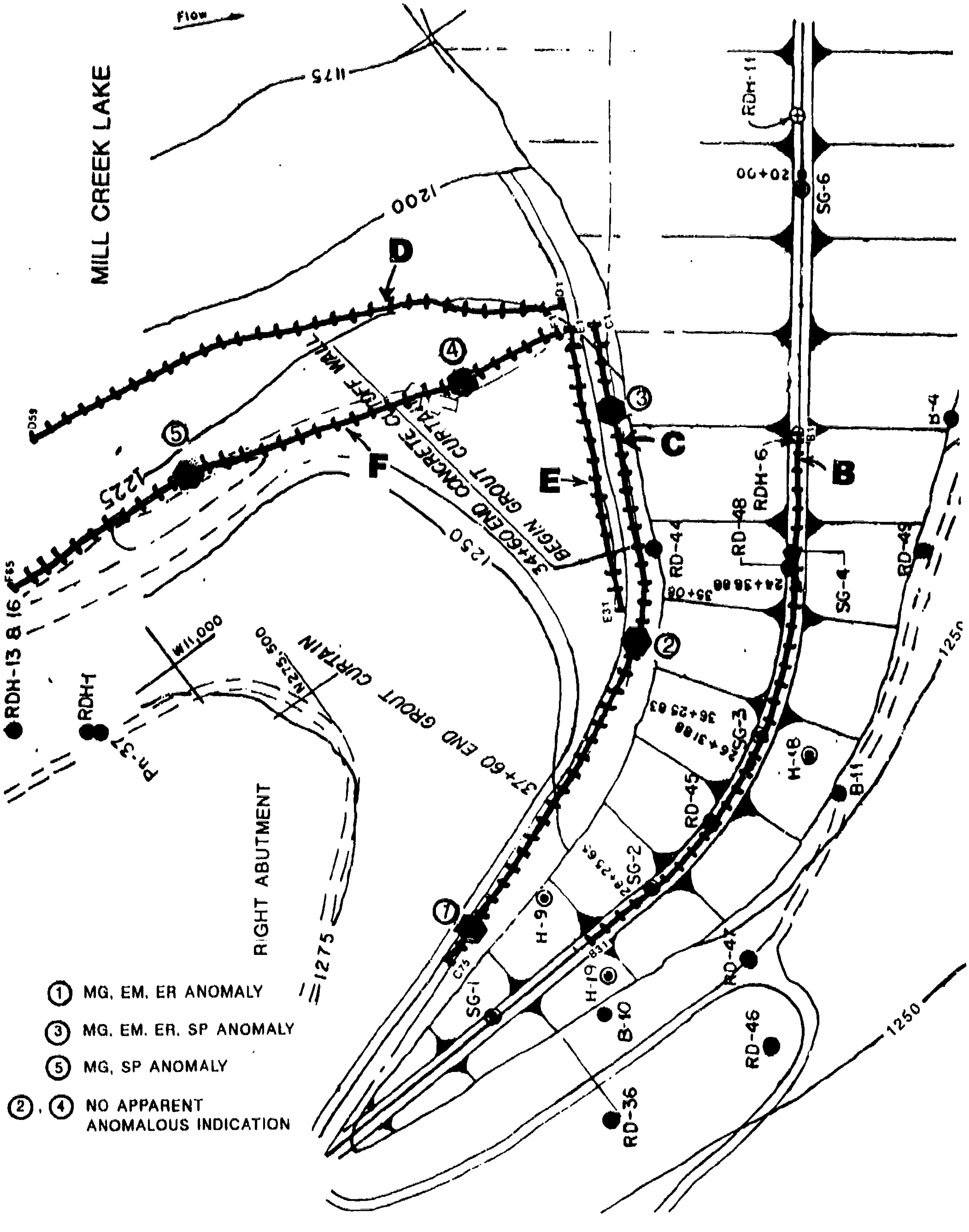


Figure 33. Recommended minimum confirmatory drilling program.

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APPENDIX A

SEISMIC REFLECTION SURVEY, MILL CREEK DAM

Great Plains Geophysical
Lawrence, Kansas

SEISMIC REFLECTION SURVEY FEASIBILITY STUDY

AT

MILL CREEK DAM

NEAR

WALLA WALLA, WASHINGTON

A REPORT PREPARED FOR

THE US ARMY CORPS OF ENGINEERS

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

BY

GREAT PLAINS GEOPHYSICAL, INC.
2913 WESTDALE ROAD
LAWRENCE, KANSAS 66049

JULY 10, 1989

Seismic reflection was used in conjunction with a variety of other geophysical techniques at Mill Creek Dam near Walla Walla, Washington to assess the embankment and foundation conditions in the dam/right abutment contact area. The reflection survey was designed to detect the suspected cavities in a silt deposit (the silt deposit is the foundation of the dam as well as the right abutment. The shallow stratigraphy of the study area includes a surface silt layer varying in thickness from 40 to 100 ft overlying an approximately 100 ft thick conglomerate which has a basalt at its basal contact. The integrity of the dam could be threatened if sinkholes similar to those detected in the floor of the reservoir continue to develop. The mechanism responsible for the cavity formation is uncertain. It is suspected that piping of silt into more pervious zones of the conglomerate could be responsible. The conglomerate may also possess cavities as a result of piping of silts from within pockets in the conglomerate.

The data were recorded on a Bison 9024 digital floating point seismograph. The seismograph has the capability to analog filter with user selectable high and low cut filters on 4 hz increments. The seismograph generates a 16 bit digital word with a two step floating point amplifier (0 or 30 dB) and a 16 bit A/D converter.

Three different sources were tested at several different filter settings at three locations (shots 1-57 at site #1, shots 58-81 at site #2, shots 83-101 at site #3) on the north end of the reservoir, for a total of 101 test shots. There are no obvious reflectors at any of the three sites with any of the parameters used. No reflection was observed from the top of the conglomerate or from within the conglomerate.

The 20 pound sledge hammer, the downhole 30.06 rifle, and the downhole .50 caliber rifle were all individually used as energy sources. The body wave energy from the rifle sources has a slightly higher frequency with less ground roll, although the hammer data are a little less 'ringy'. There was little or no seismic energy above 300 Hz, so the use of 40 Hz versus 100 Hz geophones was not critical, except to the extent that the 3 L-28E 40 Hz geophones (which were the only phones tested) have higher voltage output than the single L-40A 100 Hz geophones, given the same input ground velocity. Lo-cut filters in the 200 Hz range were efficient in removing a significant amount of ground roll.

Analysis of first arrival information (direct wave and refraction velocities versus offset) suggest the presence of a shallow refractor at a depth of 10 feet or less. The P-wave velocity in the surface layer (soil) is in the 600 to 1000 foot/second range. The velocity in the refracting layer (loess and/or silt) is in the 1400 to 3200 foot/second range. Maximum offsets were not sufficient to determine the refractive thickness of the loess layer or the velocity of the underlying conglomerate or basalt.

Two events with some subtle reflection characteristics are identifiable at two different sites and at two different times. The shallower of the two possible reflections occurs at site#1 at a time of approximately 100 msec. This event is suspect of not being a true reflection due to the highly irregular first arrival on walkaways at this site (probably the result of the slurry wall) and the lack of good coherency for more than about 10 traces. This shallower event shows a zero-distance time-intercept of 92 msec, a depth of 171 feet, and a normal-moveout velocity of 3730 ft/sec. The correlation coefficient of a least-squares hyperbola fit to the data is 0.998. Generally, anything above 0.99 is considered to be a hopeful sign of a true reflector. The first 57 test shots were fired at test site #1 which has the slurry wall present as a complication. As a result, skepticism exists concerning results at site #1.

The suggestion of reflection information can be interpreted on walkaways from site #3 (with a 200 hz or higher lowcut filter) at a time of approximately 190 msec. The event has coherency across traces with offsets less than about 80 ft. The small source to receiver offset of the two dozen or so traces with coherency results in no detectable moveout. This potential reflector has a very "broken-up" look which if real must be an indication of significant near-surface static anomalies. The nearly flat appearance of the event restricts the effectiveness of an NMO calculation to determine depth, origin time, velocity, and correlation to a hyperbola. The frequency content and sporadic nature of the coherency suggest possible spatial aliasing. The only true way to determine if this event is the result of spatial aliasing is by moving the source to a slightly different offset during acquisition. This, of course is not possible at this time.

We see no sign of reflections at site #2. It should be pointed out, however, that we did not test with the 20 pound sledge hammer at either site #2 or #3. It is possible that in our desire to work at the highest possible resolution, we prematurely ignored the sledge hammer at sites #2 and #3.

Since the data are of relatively high quality in terms of frequency and signal to noise ratio, but reflections were not readily visible, it is our conclusion that the acoustic impedance contrast at the loess/conglomerate interface was not strong enough to generate a perceptible reflection. Three different locations were tested with identical results, although the first site near the front toe of the dam had data contaminated by the presence of the slurry wall. The lack of acoustical contrast could be due to uneven cementation in the conglomerate, or it could be due to overall bulk velocity being near that of the loess. There could also be rough surfaces at the acoustical interface that inhibit reflections, although no diffraction patterns were observed that would be characteristic of some varieties of surface roughness.

Sufficient information is available to calculate the approximate size of the first Fresnel zone which gives the approximate order of direct horizontal resolution that would be possible with the reflection method. With a frequency of 150 Hz, a velocity of 3,000 feet/second, and a depth of 100 feet, the diameter of the Fresnel zone is 63 feet. For the same velocity and frequency at a depth of 200 feet, the Fresnel zone diameter is 89 feet. In other words, direct detection of voids less than perhaps 30 feet across at this site at depths of more than 100 feet would be unlikely.

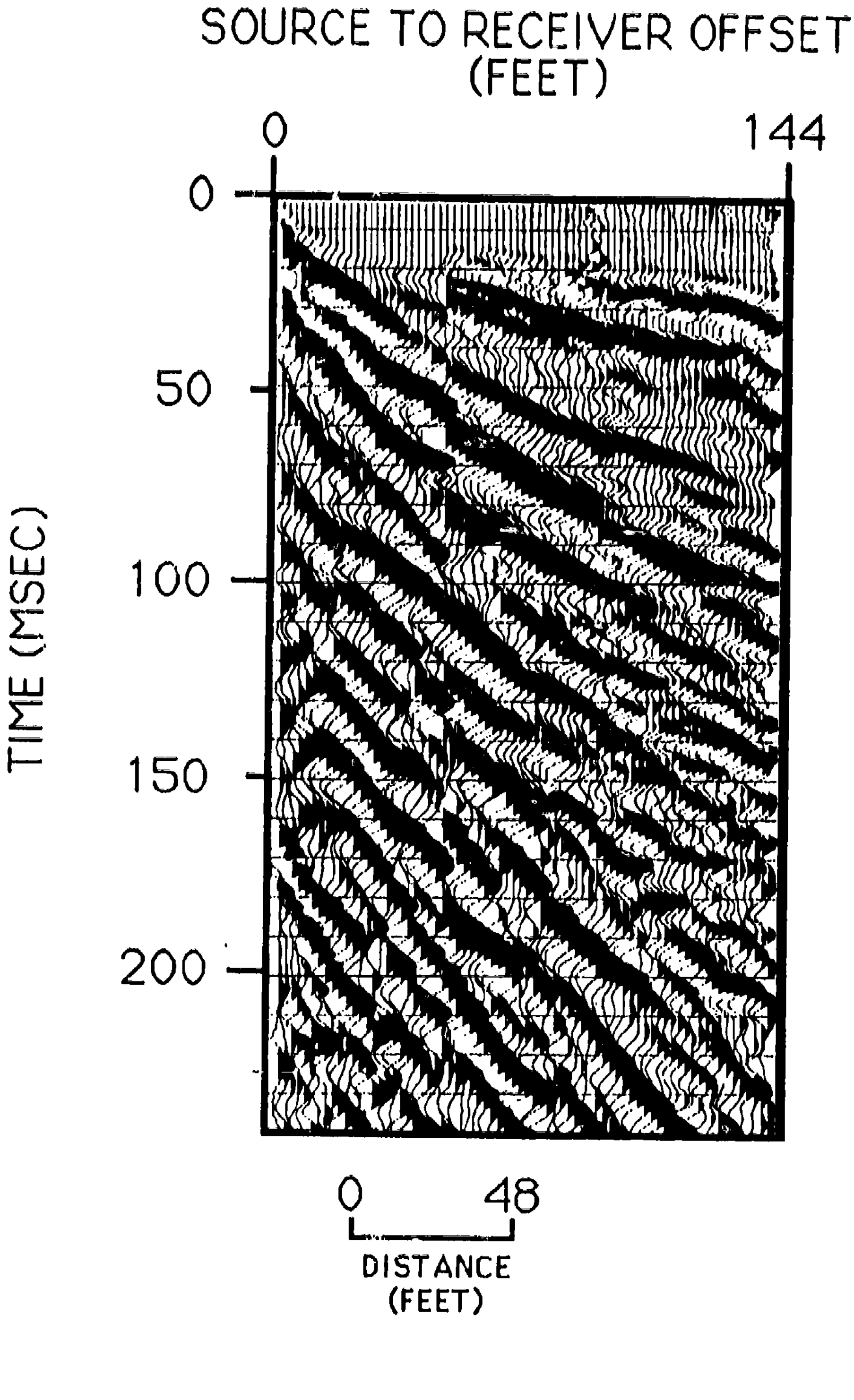
The figures generated for this report are in a walkaway format. The figure descriptions are included on a figure-by-figure basis and are somewhat redundant when compared to each other. The descriptions will however allow the separation of individual figures from this report without sacrificing the basic description of the acquisition procedure and significant information about that figure.

No digital enhancement techniques were performed on the seismic data other than variation of display parameters.

SLEDGE HAMMER SITE#1
4 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a 20 lb sledge with an approximately equivalent weight steel plate. The 4 hz lowcut filters were the lowest low cut available on the seismograph, they therefore represent lowcuts out. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 46 ft and 48 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec.

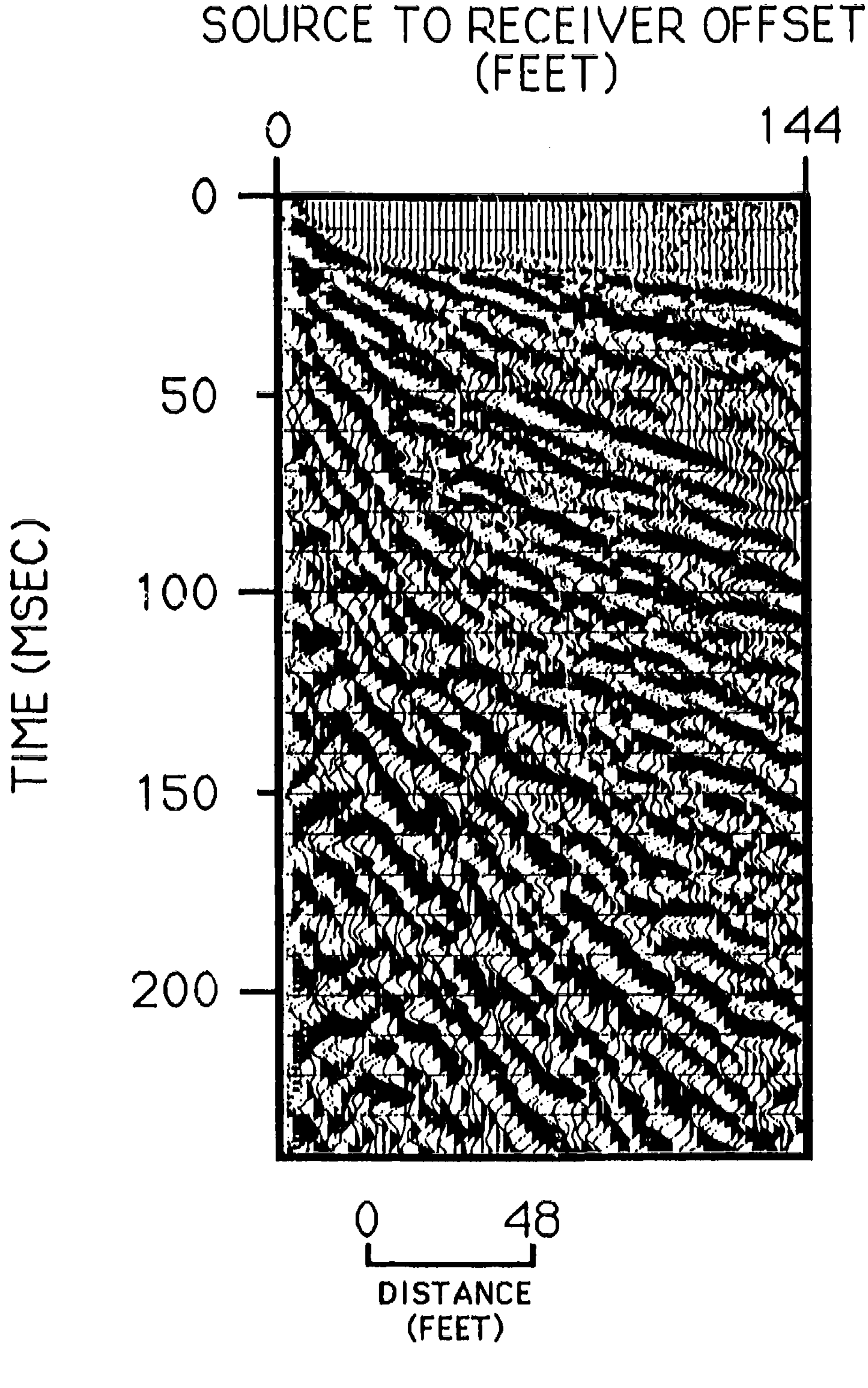
SLEDGE HAMMER SITE # 1
4 HZ ANALOG LOWCUT FILTER



SLEDGE HAMMER SITE#1
128 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a 20 lb sledge with an approximately equivalent weight steel plate. The 128 hz lowcut filters used during recording of this walkaway possess a 18 dB/octave slope. The geophone spread used for this walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 46 ft and 48 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. The dominant frequency of the recorded signal is approximately 100 hz. The bandwidth of the recorded signal is relatively broad with frequencies ranging from 40 to about 300 hz. No clearly identifiable reflection signal is present on this walkaway.

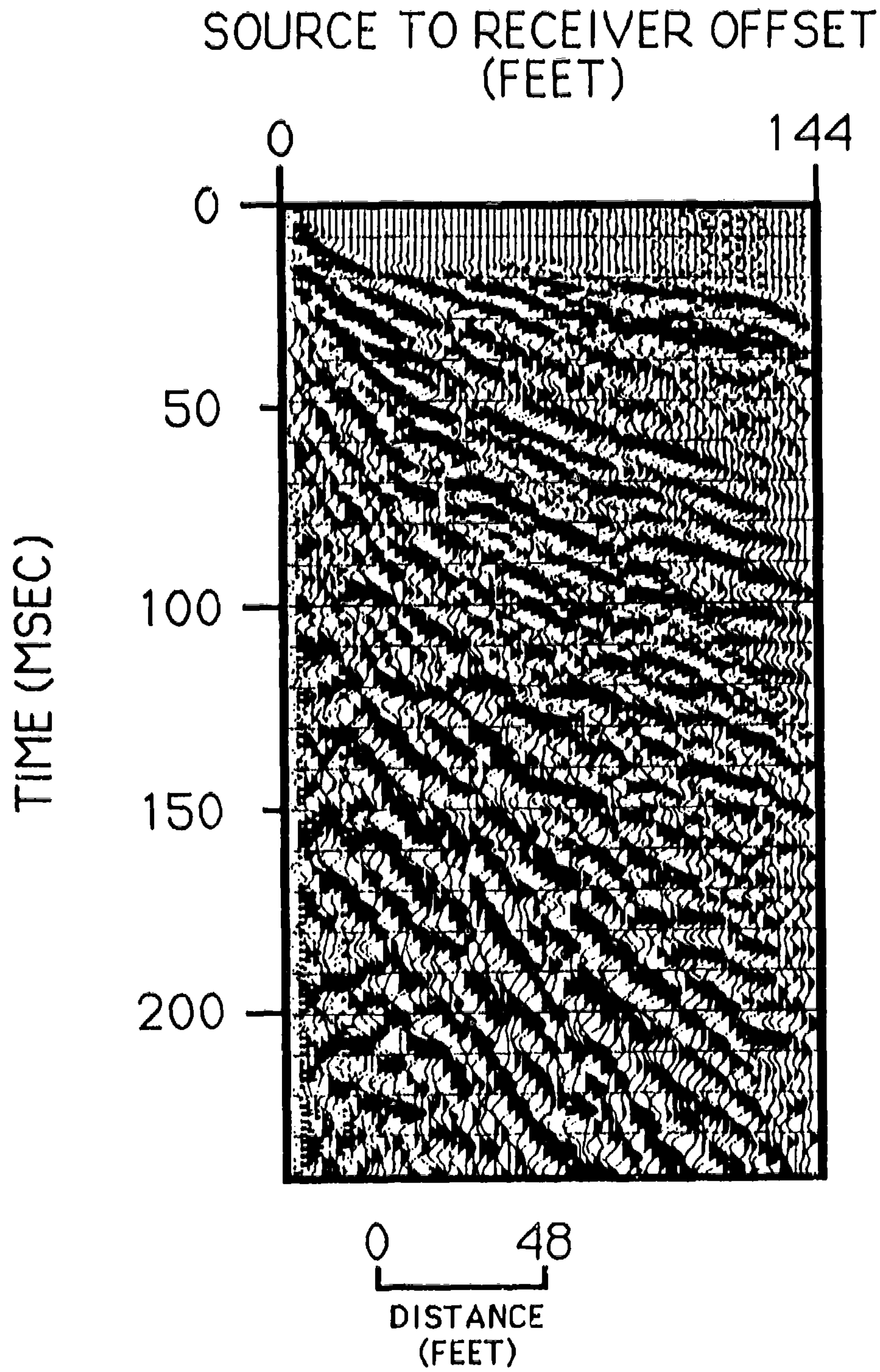
SLEDGE HAMMER SITE# 1
128 HZ ANALOG LOWCUT FILTER



SLEDGE HAMMER SITE#1
256 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a 20 lb sledge with an approximately equivalent weight steel plate. The 256hz lowcut filters used during recording of this walkaway possess a 18 dB/octave slope. The geophone spread used for this walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 46 ft and 48 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. At offsets in excess of 100 ft at approximately 100 msec an event with some reflection characteristics can be interpreted. The curvature of this event in conjunction with its arrival time suggest a depth of approximately 170 ft. The air wave is identifiable on this walkaway. The dominant frequency of the recorded signal is approximately 120 hz. The bandwidth of the recorded signal is relatively broad with frequencies ranging from 40 to about 300 hz.

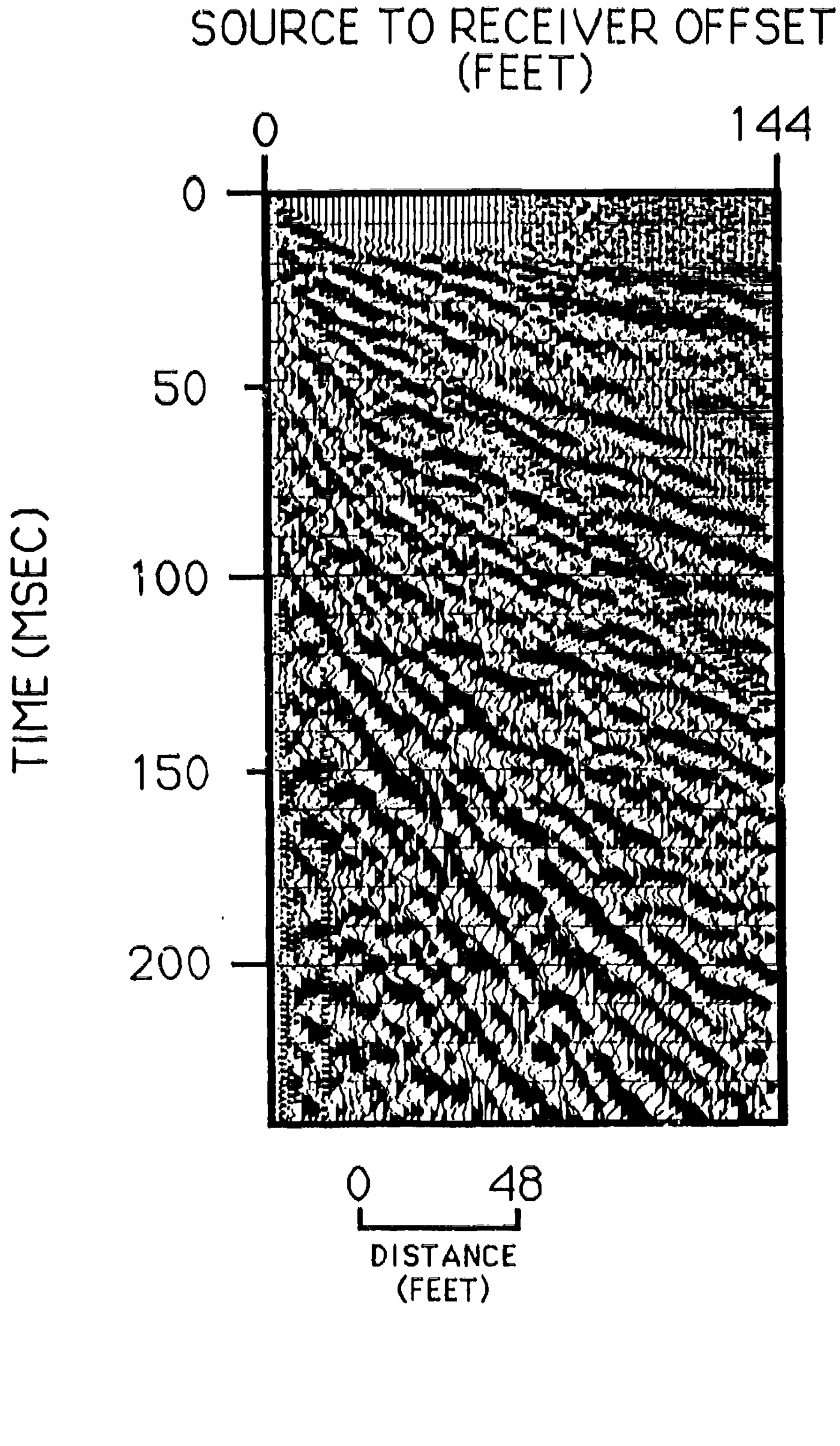
SLEDGE HAMMER SITE # 1
256 HZ ANALOG LOWCUT FILTER



SLEDGE HAMMER SITE#1
384 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a 20 lb sledge with an approximately equivalent weight steel plate. The 384 hz lowcut filters used during recording of this walkaway possess a 18 dB/octave slope. The geophone spread used for this walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 46 ft and 48 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. At offsets in excess of 100 ft at approximately 100 msec an event with some reflection characteristics can be interpreted. The curvature of this event in conjunction with its arrival time suggest a depth of approximately 170 ft. The air wave is identifiable on this walkaway. The dominant frequency of the recorded signal is approximately 150 hz. The bandwidth of the recorded signal is relatively broad with frequencies ranging from 40 to about 300 hz. The high frequency (600 hz) horizontally coherent spikes obvious above 90 msec at offsets greater than 90 ft area equipment related and do not represent recorded acoustical energy.

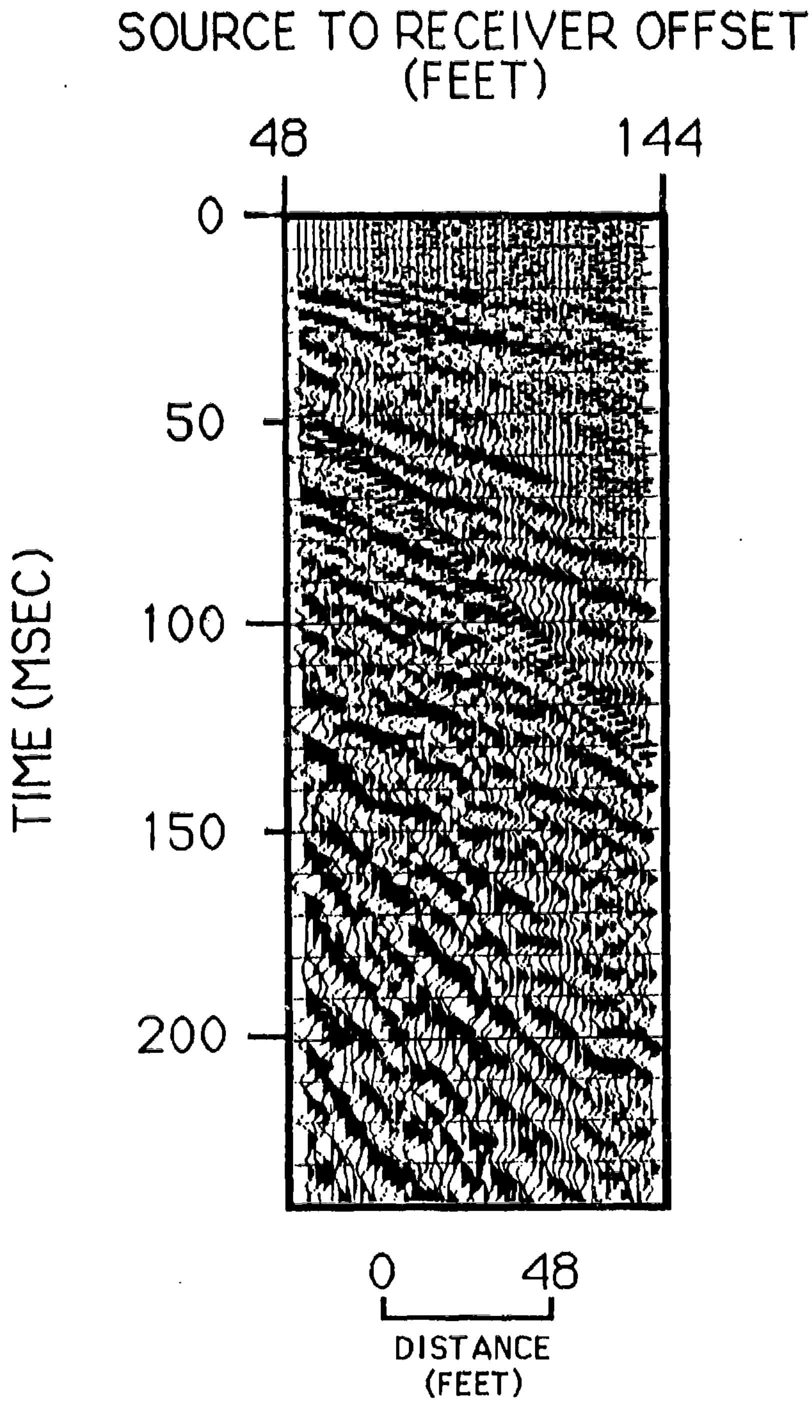
SLEDGE HAMMER SITE # 1
384 HZ ANALOG LOWCUT FILTER



SLEDGE HAMMER SITE#1
512 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers with minimum source to receiver offset of 48 ft and maximum source to receiver offset of 144 ft. The source was a 20 lb sledge with an approximately equivalent weight steel plate. The 512 hz lowcut filters used during recording of this walkaway possess a 18 dB/octave slope. The geophone spread used for this walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. At offsets in excess of 100 ft at approximately 100 msec an event with some reflection characteristics can be interpreted. The curvature of this event in conjunction with its arrival time suggest a depth of approximately 170 ft. The air wave is identifiable on this walkaway. The dominant frequency of the recorded signal is approximately 150 hz. The bandwidth of the recorded signal is relatively broad with frequencies ranging from 40 to about 300 hz. The increased amounts of high frequency noise present on the early portions of the record, results from the removal of a significant amount of lower frequency signal by the severe lowcut filter. This severe filtering allows low amplitude noise to become a more significant portion of the data set.

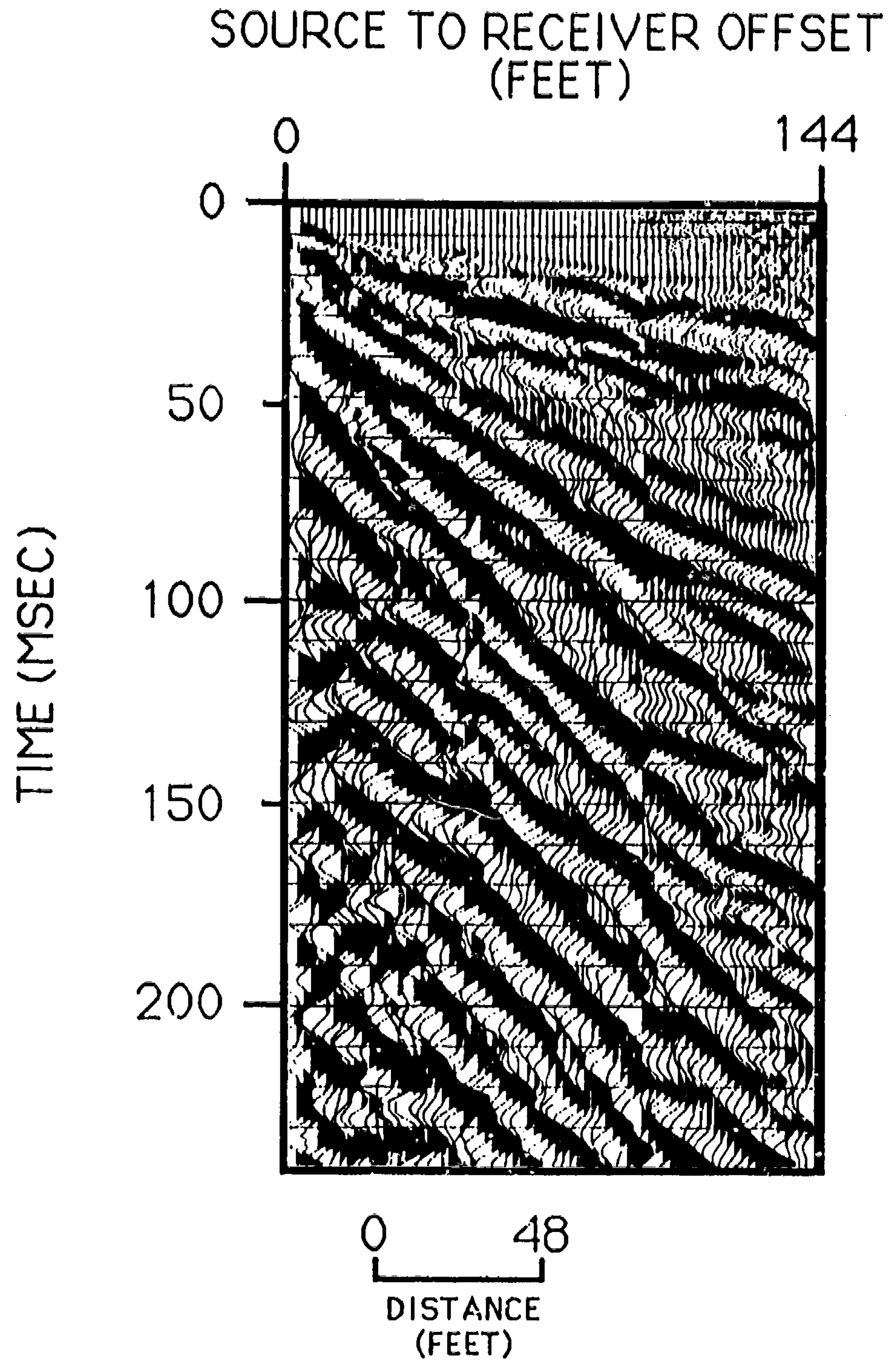
SLEDGE HAMMER SITE # 1
512 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#1
4 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 4 hz lowcut filters were the lowest low cut available on the seismograph, they therefore represent lowcuts out. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 94 ft and 96 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. The 4 hz walkaway with the sledge hammer and steel plate is quite consistent with this 4 hz walkaway. The main distinction is the frequency of the identifiable body wave energy. The 30.06 appears to have a dominant frequency at least 30 to 40 hz higher.

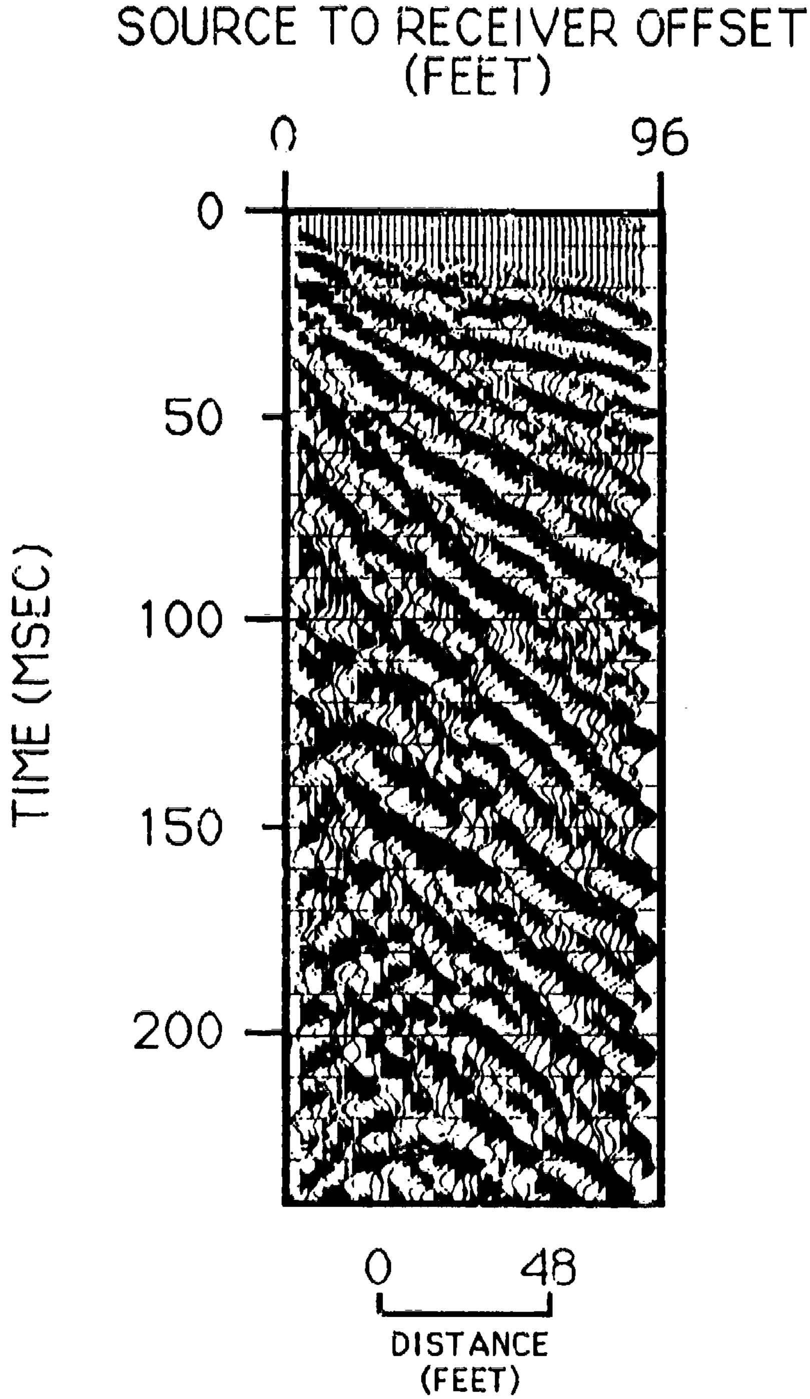
DOWNHOLE 30.06 SITE#1
4 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#1
128 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 128 hz lowcut filters provide a 18 dB/octave rolloff. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The apparent phase anomaly between receivers at 46 ft and 48 ft are the result of source static. The 30.06 rifle was fired into the same hole for several shots. This procedure in some environments can result in a slight time discrepancy on multi-file walkaways. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. No obvious primary reflection energy can be interpreted on this walkaway.

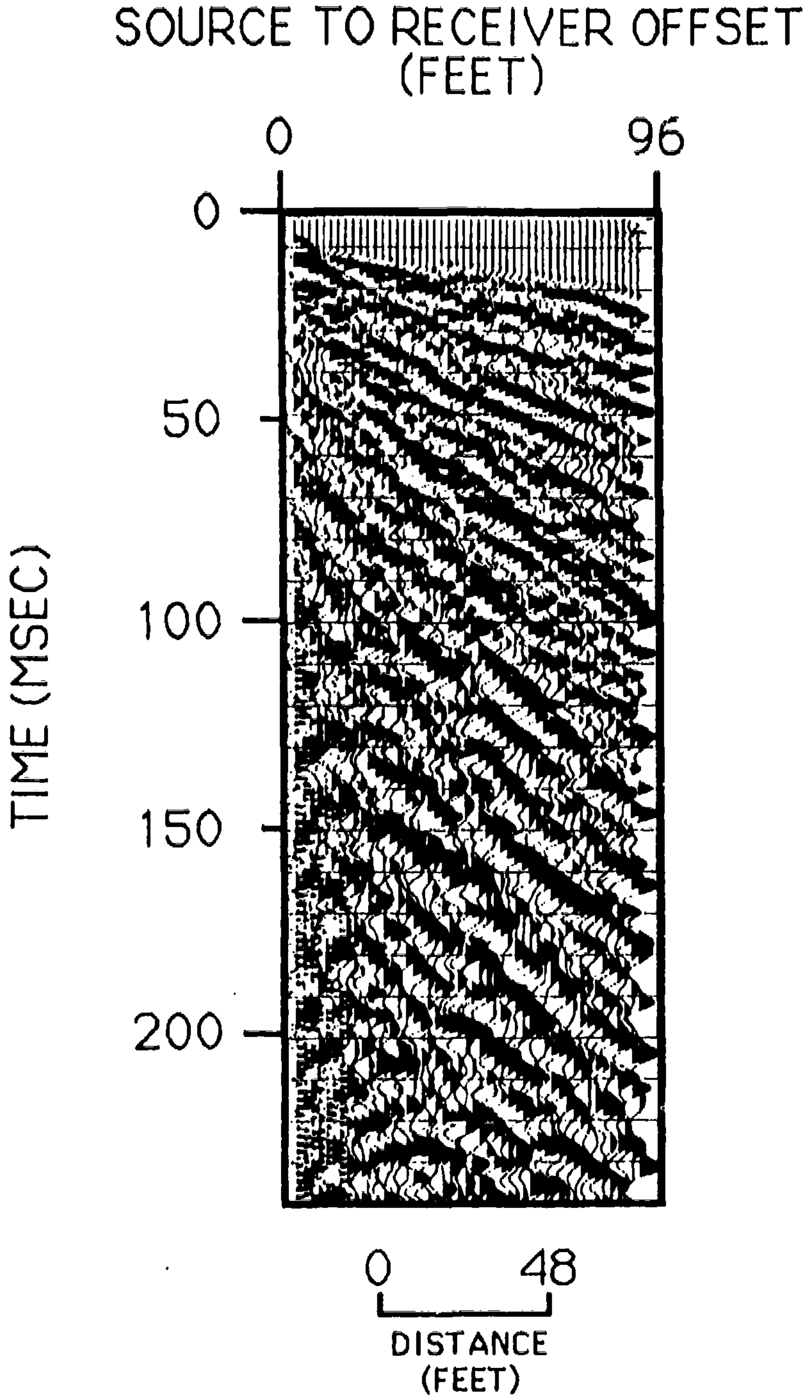
DOWNHOLE 30.06 SITE# 1
128 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#1
256 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 256 hz lowcut filters provide a 18 dB/octave rolloff. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The apparent phase anomaly between receivers at 46 ft and 48 ft are the result of source static. The 30.06 rifle was fired into the same hole for several shots. This procedure in some environments can result in a slight time discrepancy on multi-file walkaways. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. There appears to be more coherent energy above the airwave and below the refracted arrival on the 30.06 data in comparison to equivalent sledge hammer data. The frequency of the 30.06 body wave information possess a slightly higher frequency. No obvious primary reflection energy can be interpreted on this walkaway.

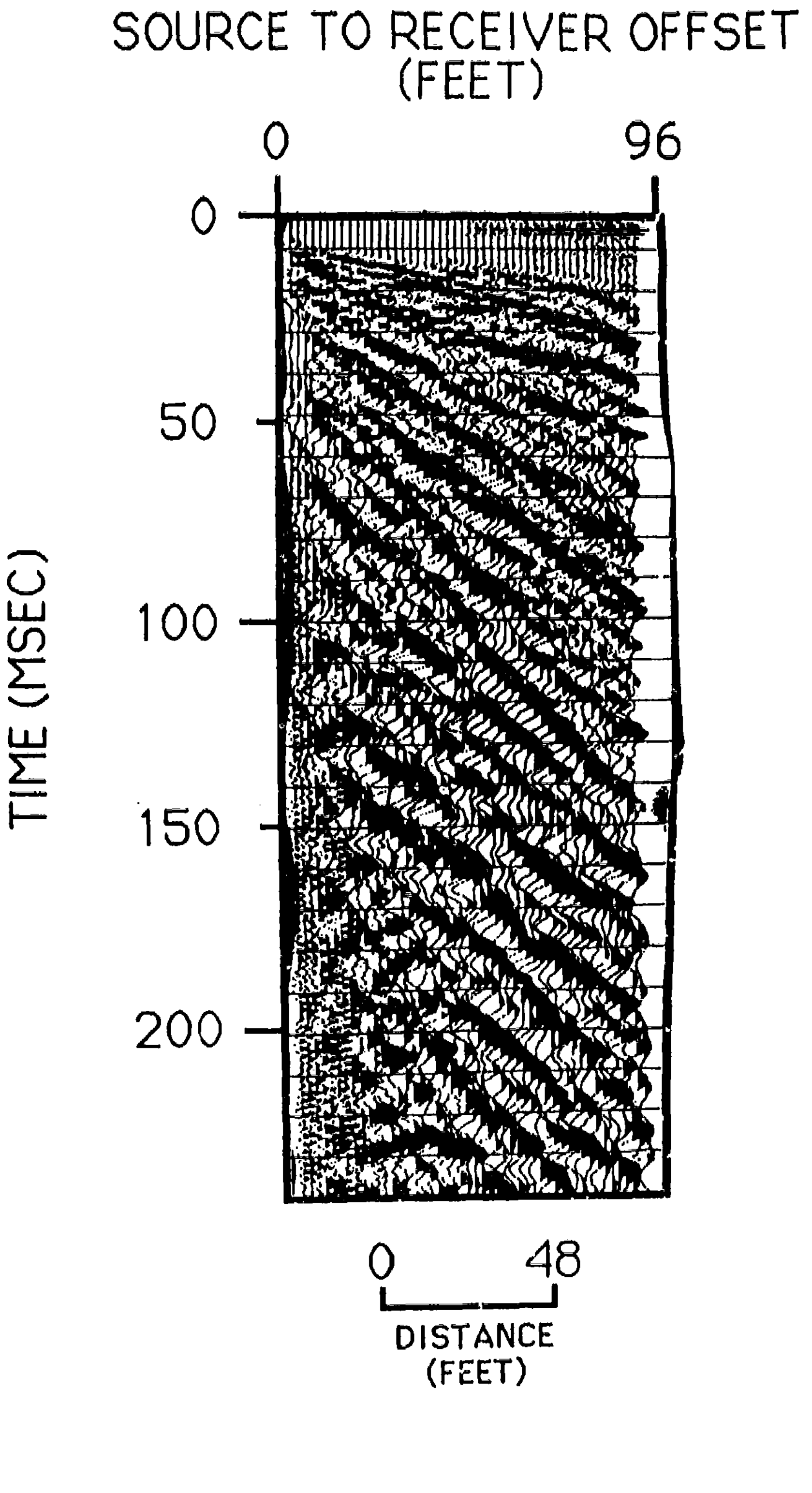
DOWNHOLE 30.06 SITE# 1
256 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#1
512 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 512 hz lowcut filters provide a 18 dB/octave rolloff. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The apparent phase anomaly between receivers at 46 ft and 48 ft are the result of source static. The 30.06 rifle was fired into the same hole for several shots. This procedure in some environments can result in a slight time discrepancy on multi-file walkaways. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. There appears to be more coherent energy above the airwave and below the refracted arrival on the 30.06 data in comparison to equivalent sledge hammer data. The frequency of the 30.06 body wave information possess a slightly higher frequency. There appears to be little difference between the 256 lowcut and the 512 lowcut except for a slightly higher amount of electronic noise evident pre-first arrival on the more distant set of 24 channels (48-96 ft). No obvious primary reflection energy can be interpreted on this walkaway.

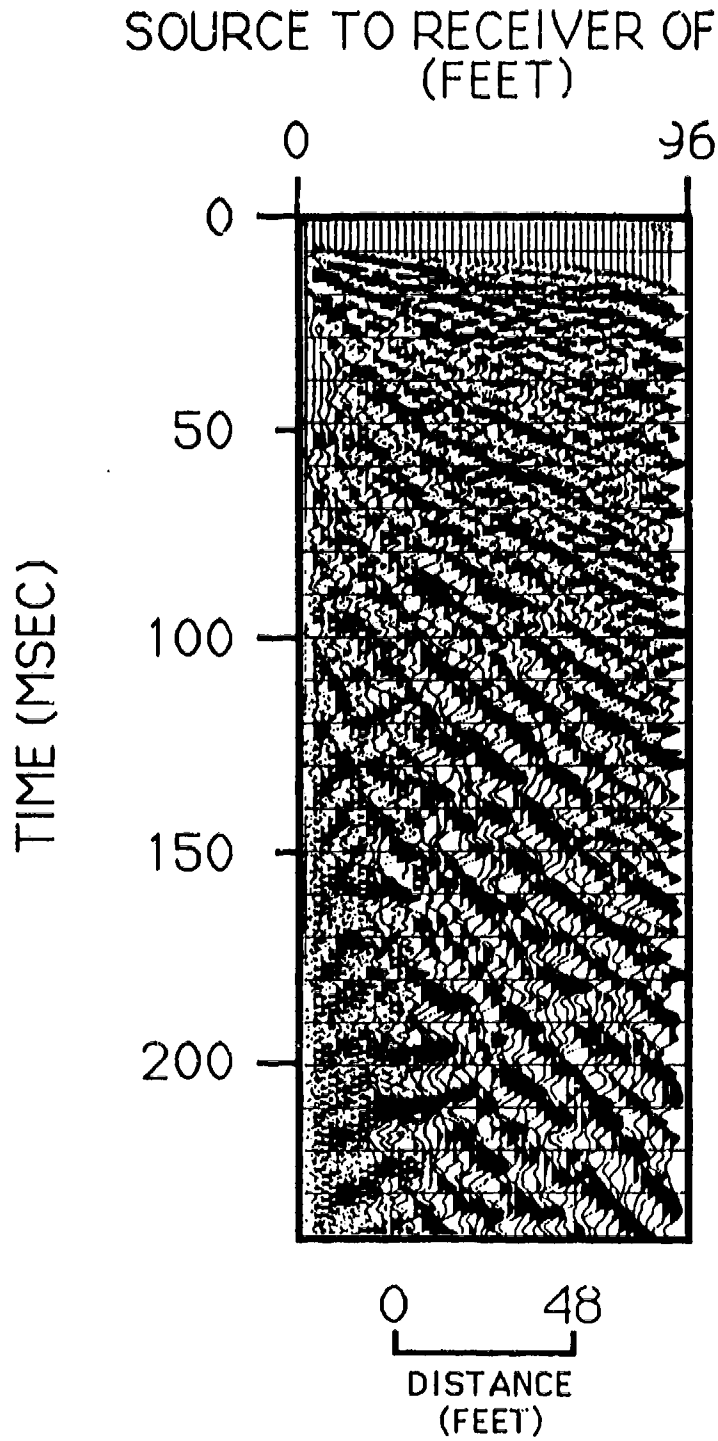
DOWNHOLE 30.06 SITE# 1
512 HZ ANALOG LOWCUT FILTER



DOWNHOLE 50 CAL SITE#1
384 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 50 cal rifle firing a 750 grain projectile. The 384 hz lowcut filters provide a 18 dB/octave rolloff. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The apparent phase anomaly between receivers at 46 ft and 48 ft are the result of source static. The 50 cal rifle was fired into the same hole for several shots. This procedure in some environments can result in a slight time discrepancy on multi-file walkaways. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. There appears to be more coherent energy above the airwave and below the refracted arrival on the 50 cal data in comparison to either equivalent sledge hammer or 30.06 data. A significantly larger amount of total energy is generated by the 50 cal than either of the other 2 source tried at this location. No obvious primary reflection energy can be interpreted on this walkaway.

DOWNHOLE 50 CAL SITE# 1
384 HZ ANALOG LOWCUT FILTER



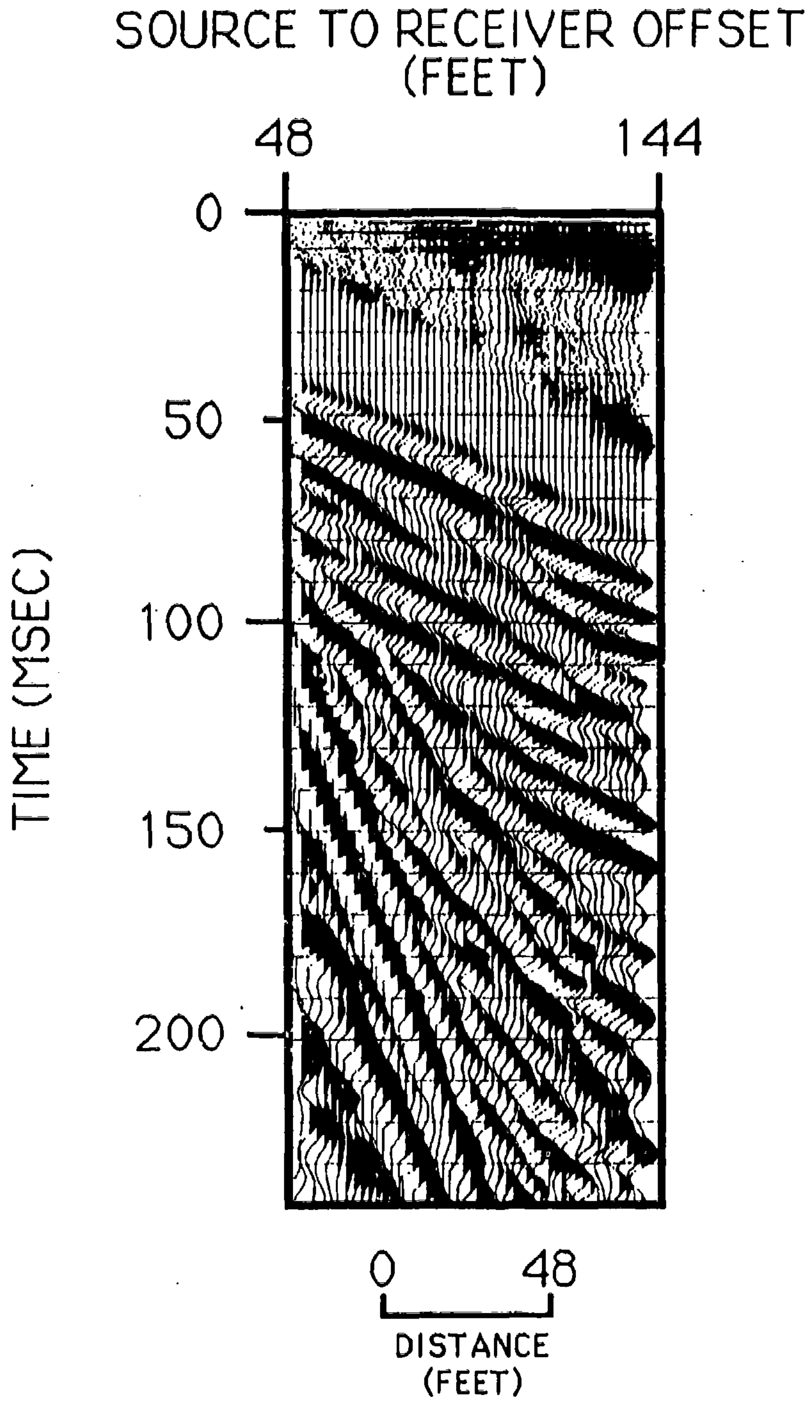
DOWNHOLE 50 CAL SITE#1
512 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 50 cal rifle firing a 750 grain projectile. The 512 hz lowcut filters provide a 18 dB/octave rolloff. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. The apparent phase anomaly between receivers at 46 ft and 48 ft are the result of source static. The 50 cal rifle was fired into the same hole for several shots. This procedure in some environments can result in a slight time discrepancy on multi-file walkaways. The direct and refracted arrivals on this walkaway, as on all walkaways at site#1, are very unusual (in amplitude, trace to trace phase, and relative arrival pattern) and seem to indicated significant near-surface structure. The direct wave arrival on this record is quite substantial with respect to amplitude. The wavelet associated with the direct wave appears to 'ring' throughout the recording period. This cyclic nature of the first arrival maybe characteristic of this area. The direct wave velocity at this site appears to be approximately 1500 ft/sec. The apparent first refracting velocity is approximately 4800 ft/sec. There appears to be more coherent energy above the airwave and below the refracted arrival on the 50 cal data in comparison to either equivalent sledge hammer or 30.06 data. A significantly larger amount of total energy is generated by the 50 cal than either of the other 2 source tried at this location. Most of the arrivals within the time window between the refractions and the ground roll have a slope very similar to either the refractions or the direct wave. Making the likelihood of any of those events being reflections relatively poor. No obvious primary reflection energy can be interpreted on this walkaway.

DOWNHOLE 30.06 SITE#2
4 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 4 hz lowcut filters were the lowest low cut available on the seismograph, they therefore represent lowcuts out. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 94 ft and 96 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways from this site and site #3 are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 750 ft/sec. The apparent first refracting velocity is approximately 1400 ft/sec. As at site#1, the majority of the energy arriving within the classicaliy quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram.

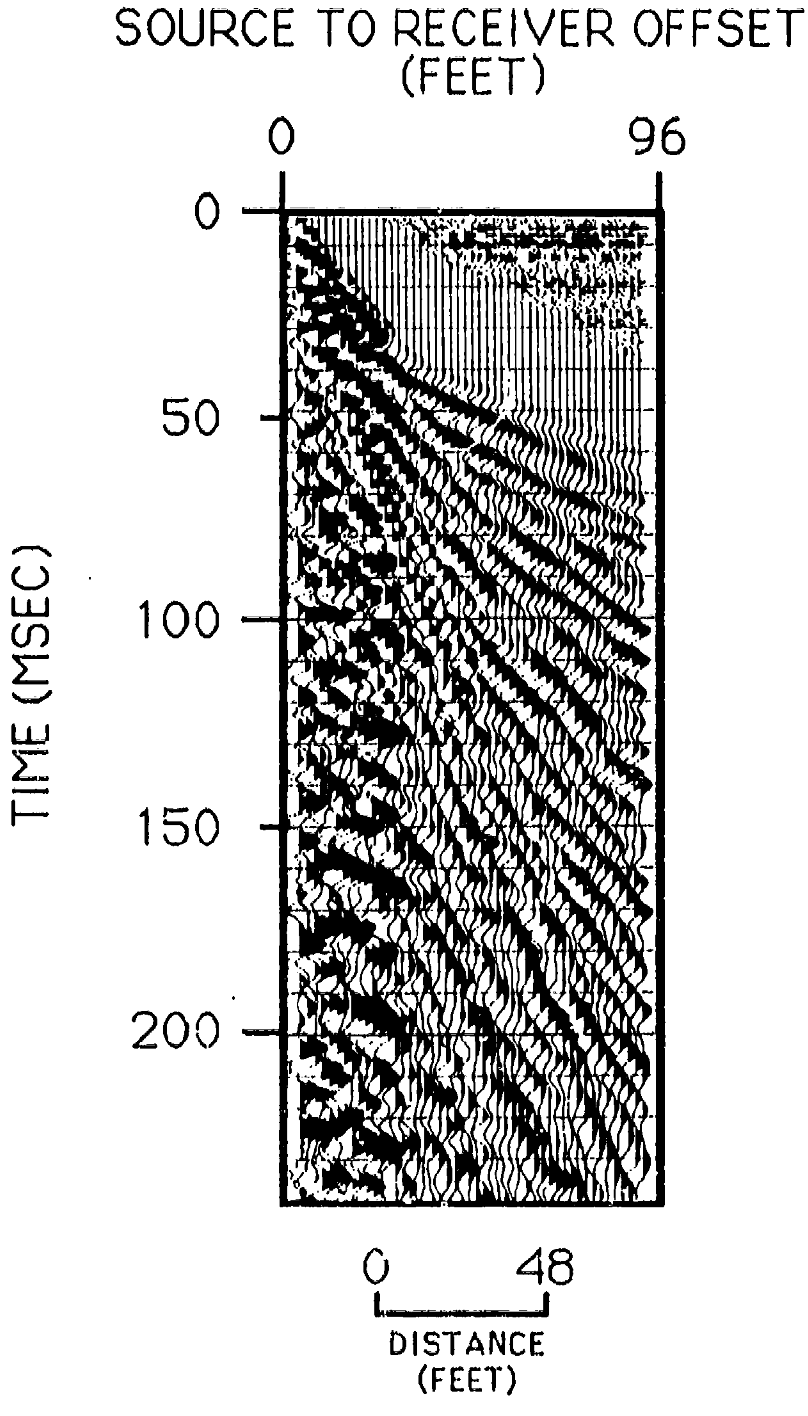
DOWNHOLE 30.06 SITE#2
4 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#2
128 HZ ANALOG LOWCUT FILTER

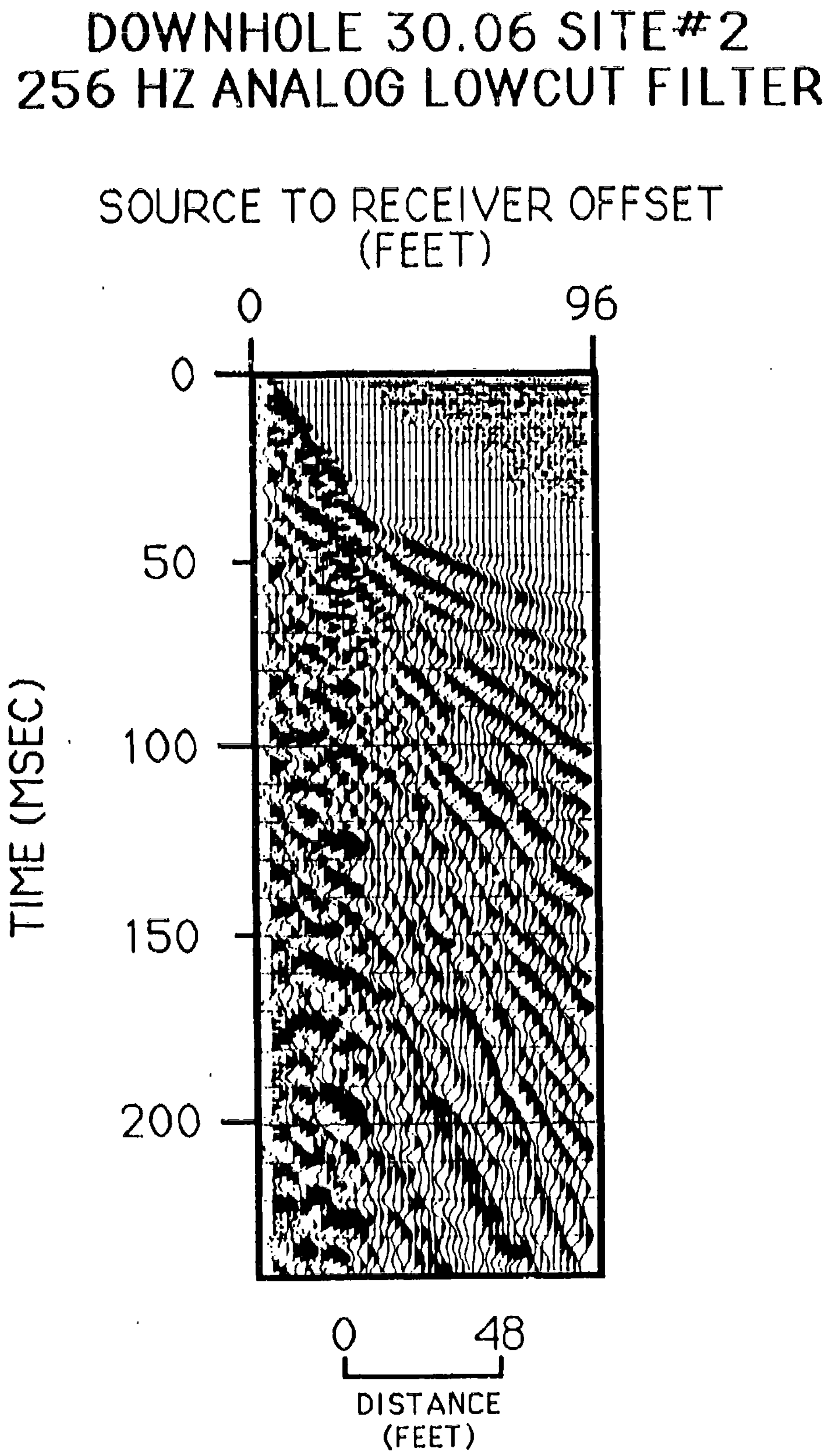
This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 128 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for both shot but the second shot in the hole will have a slightly different travel path than the first. This different travel path is mainly represented as deeper penetration. The direct and refracted arrivals on this walkaway, as on all walkaways from this site and site #3 are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 750 ft/sec. The apparent first refracting velocity is approximately 1400 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram. The ground roll arrivals at offsets less than 15 ft lack coherency. This is probably related to the low cut filtering of the systems filters and the 40 hz geophones.

DOWNHOLE 30.06 SITE#2
128 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#2
256 HZ ANALOG LOWCUT FILTER

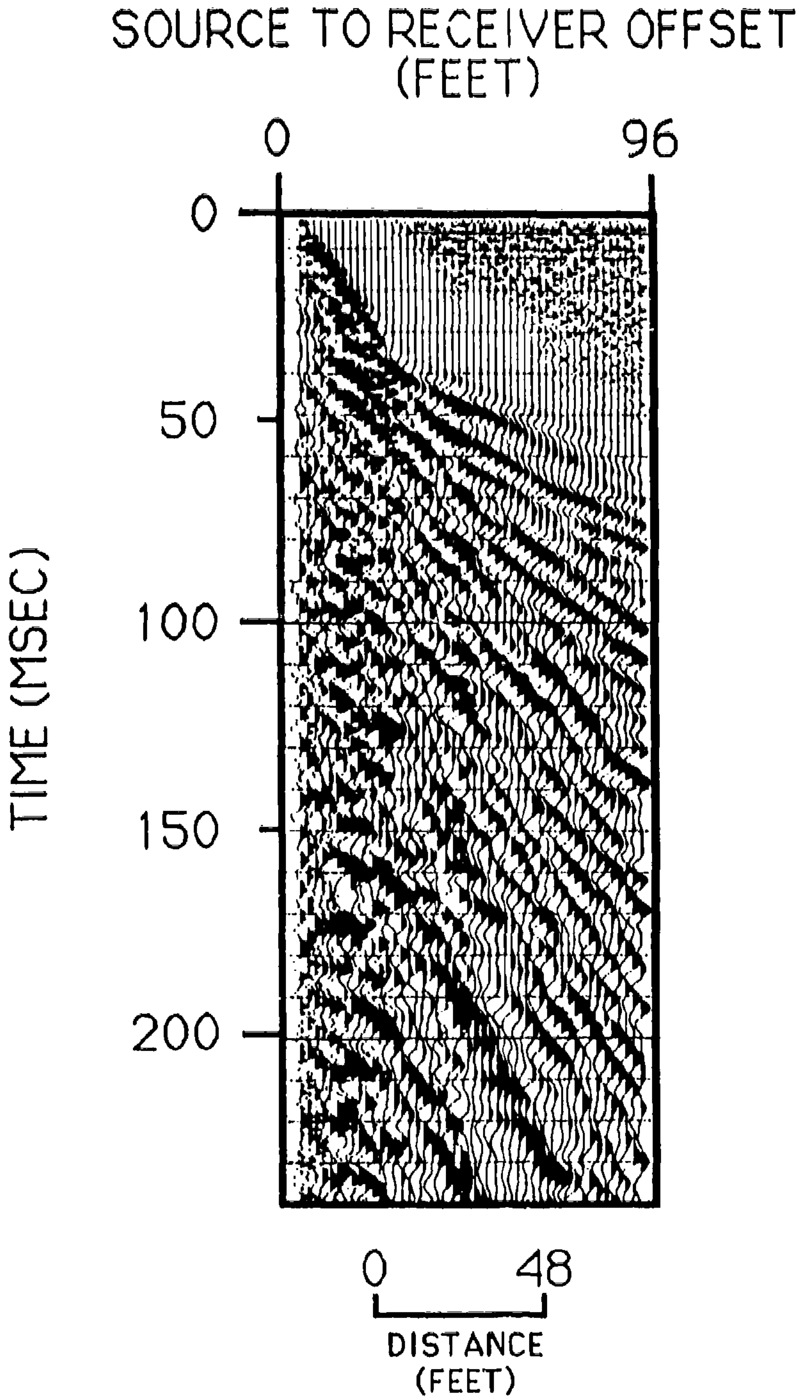
This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 256 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for both shot but the second shot in the hole will have a slightly different travel path than the first. This different travel path is mainly the result of deeper penetration of the second shot in comparison to the first. The direct and refracted arrivals on this walkaway, as on all walkaways from this site and site #3 are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 750 ft/sec. The apparent first refracting velocity is approximately 1400 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram. The ground roll arrivals at offsets less than 15 ft lack coherency. This is probably related to the low cut filtering of the systems filters and the 40 hz geophones.


DOWNHOLE 30.06 SITE#2
256 HZ ANALOG LOWCUT FILTER
SOURCE TO RECEIVER OFFSET
(FEET)
0
96
TIME (MSEC)
0
50
100
150
200
0
48
DISTANCE
(FEET)

DOWNHOLE 30.06 SITE#2
384 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 384 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for both shot but the second shot in the hole will have a slightly different travel path than the first. This different travel path is mainly the result of deeper penetration of the second shot in comparison to the first. The direct and refracted arrivals on this walkaway, as on all walkaways from this site and site #3 are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 750 ft/sec. The apparent first refracting velocity is approximately 1400 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. The dominant frequency of the body wave energy is noticeably higher on this record than on the previous records with lower lowcut filters from this location. No reflection events can be confidently identified on this seismogram. The ground roll arrivals at offsets less than 15 ft lack coherency. This is probably related to the low cut filtering of the systems filters and the 40 hz geophones.

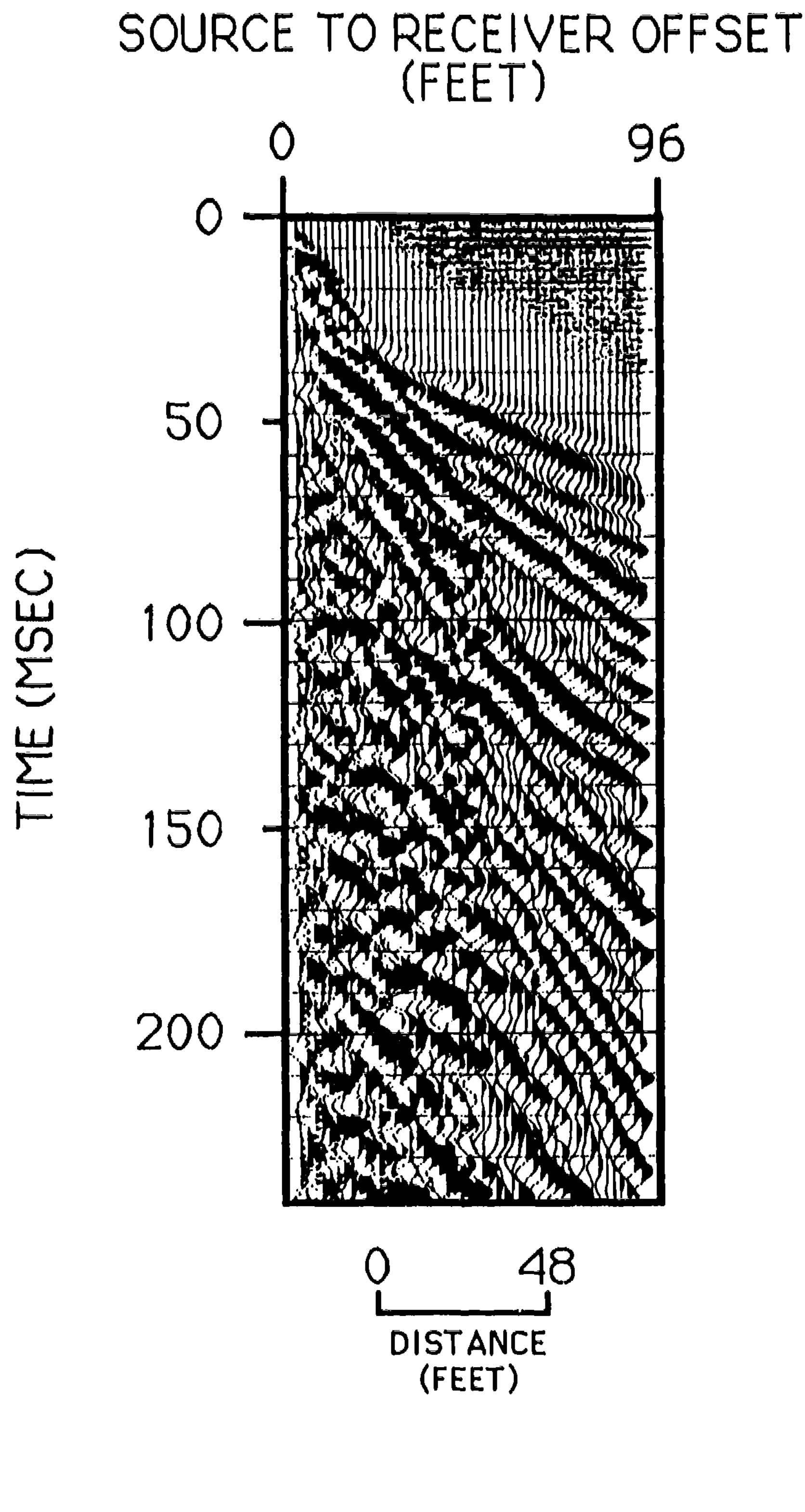
DOWNHOLE 30.06 SITE#2
384 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#2
512 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 50 cal rifle firing a 750 grain projectile. The 512 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for both shots that make up this walkaway. The second shot (recording the longer offsets) in the hole had slightly deeper penetration in comparison to the first. The direct and refracted arrivals on this walkaway, as on all walkaways from this site and site #3 are much more characteristic of "normal" first arrivals patterns. The direct wave velocity at this site appears to be approximately 750 ft/sec. The apparent first refracting velocity is approximately 1400 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram. The 50 cal clearly generates more recordable seismic energy than either the 30.06 or the sledge hammer and plate. As with some of the earlier walkaways, pre-first arrival noise can be interpreted. The frequency and coherency of the energy is indicative of instrument noise. The ground roll arrivals at offsets less than 15 ft lack trace to trace coherency. This is probably related to the low cut filtering of the systems filters and the 40 geophones. Coherent energy arrivals beyond 48 ft of offset and deeper in time than approximately 100 msec on the seismogram possess a variety of phase velocities.

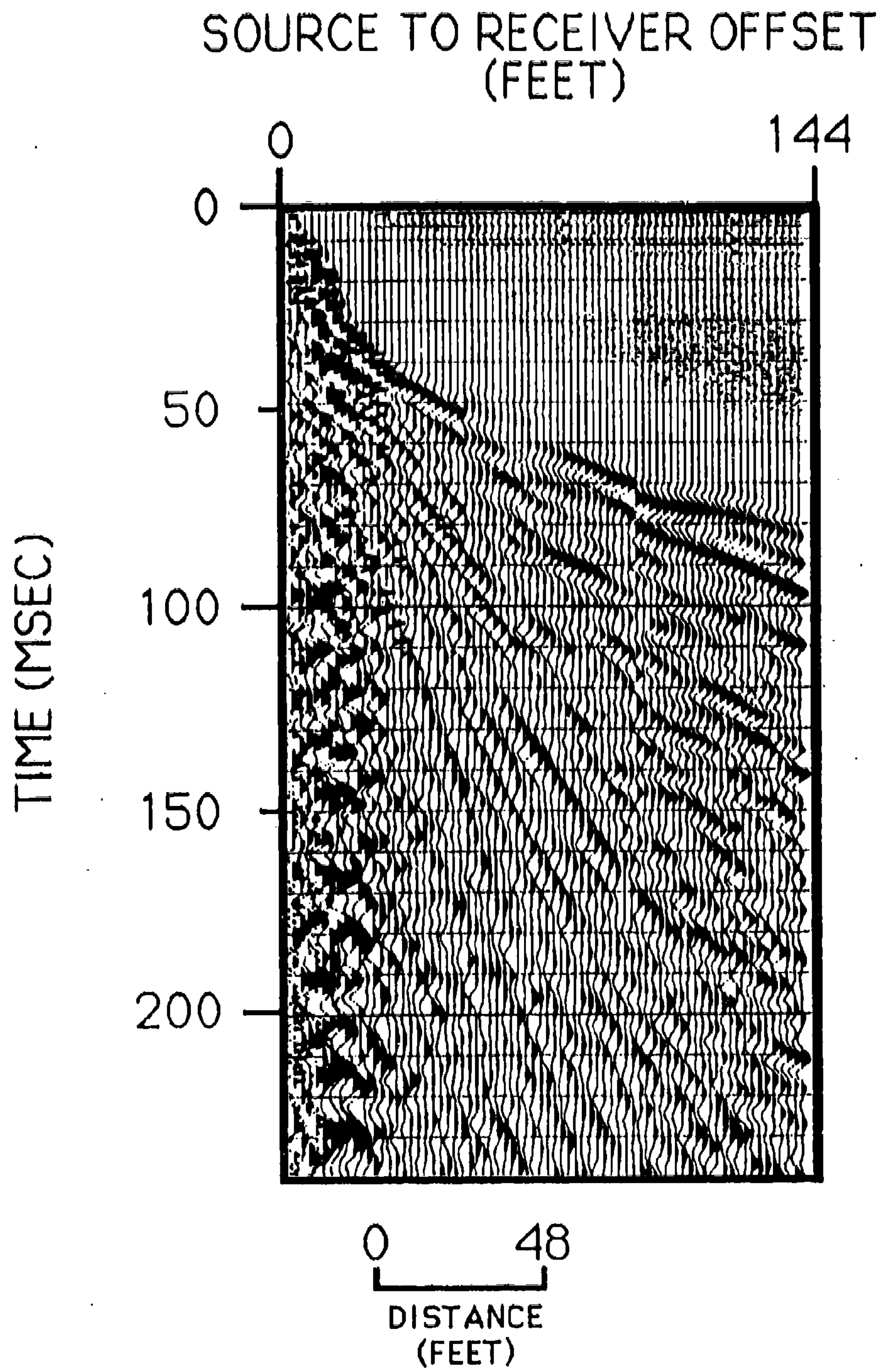
DOWNHOLE 50 CAL SITE#2
512 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#3
384HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 384 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for the first and second shots. The shot recorded at the longer offset had a slightly different depth of penetration than the first shot in the hole. The slight phase mismatch between the traces at 96 and 98 ft of offset is a result of the different source location and therefore a different source static. The direct and refracted arrivals on this walkaway, as on all walkaways from this site are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 625 ft/sec. The apparent first refracting velocity is approximately 1900 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram. The high frequency spikes on the inside 24 traces within the first 100 msec is the result of overdriving the analog filters. The operator of the seismograph has no way of knowing if the filters are overdriven except through visual inspection of field plots. The event previously identified at 190 msec as a potential reflected event is present but much more obscured on this walkaway than of the 256 hz lowcut display. The probably of this event being a reflection is neither enhanced or reduced as a result of analysis of this walkaway. The ground roll arrivals at offsets less than 15 ft lack coherency. This is probably related to the low cut filtering of the systems filters and the 40 hz geophones. Three distinctly different phase velocities can be identified.

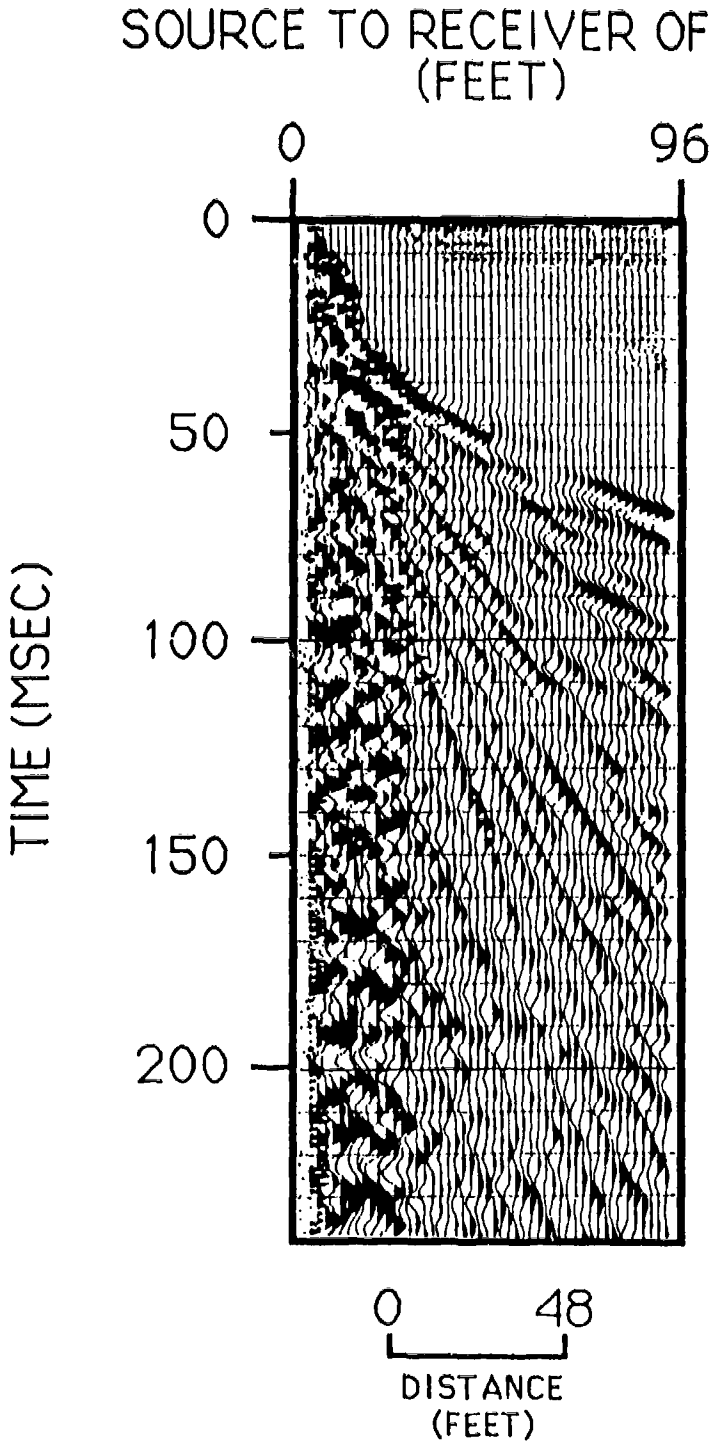
DOWNHOLE 30.06 SITE#3
384 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#3
256 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 96 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 256 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for both shots. The second shot in the hole penetrated deeper, as a direct result of the first shots, intuitively obvious deepening of the hole. The deeper hole allowed the second projectile to dissipate it's energy into material possessing a slightly different velocity as well as travel longer in the air of the borehole. The direct and refracted arrivals on this walkaway, as on all walkaways from this site are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 600 ft/sec. The apparent first refracting velocity is approximately 1800 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. A subtle hint of coherency can be identified at approximately 190 msec on th inside 35 traces. This event possess to high a velocity at these offsets and trace spacings to confidently calculate the NMO velocity. With some spectral analysis and digital filtering this event could possibly be enhanced. Some possibility of spatial aliasing exists with this event. The only way to confidently eliminate that possibility is by varying the source offset slightly. This of course is not an option at this time. An F-k filter probably would enhance the coherency of this event. The frequency and lack of good coherency suggests caution be taken in confidently identifying this event as a reflection.

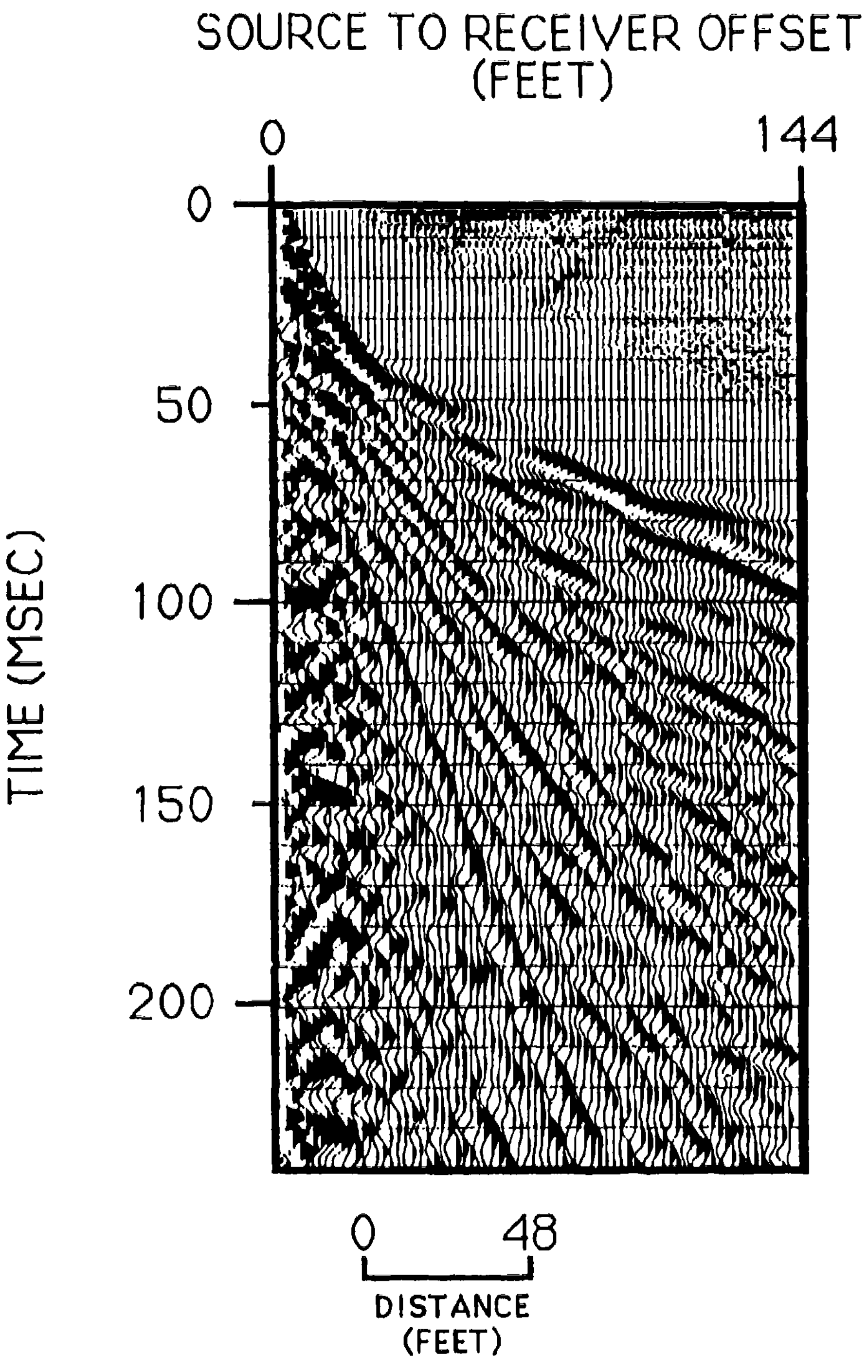
DOWNHOLE 30.06 SITE#3
256 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#3
128 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 128 hz lowcut filters have an 18 dB/octave slope. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. A slight mismatch can be observed between offsets 46 and 48 as a result of different recorded shots. The same hole was occupied for the first and second shots. The shot recorded at the longer offset had a slightly different depth of penetration than the first shot in the hole. The slight phase mismatch between the traces at 96 and 98 ft of offset is a result of the different source location and therefore a different source static. The direct and refracted arrivals on this walkaway, as on all walkaways from this site are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 625 ft/sec. The apparent first refracting velocity is approximately 1900 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. No reflection events can be confidently identified on this seismogram. The ground roll arrivals at offsets less than 15 ft lack coherency. This is probably related to the low cut filtering of the systems filters and the 40 hz geophones. Three distinctly different phase velocities can be identified.

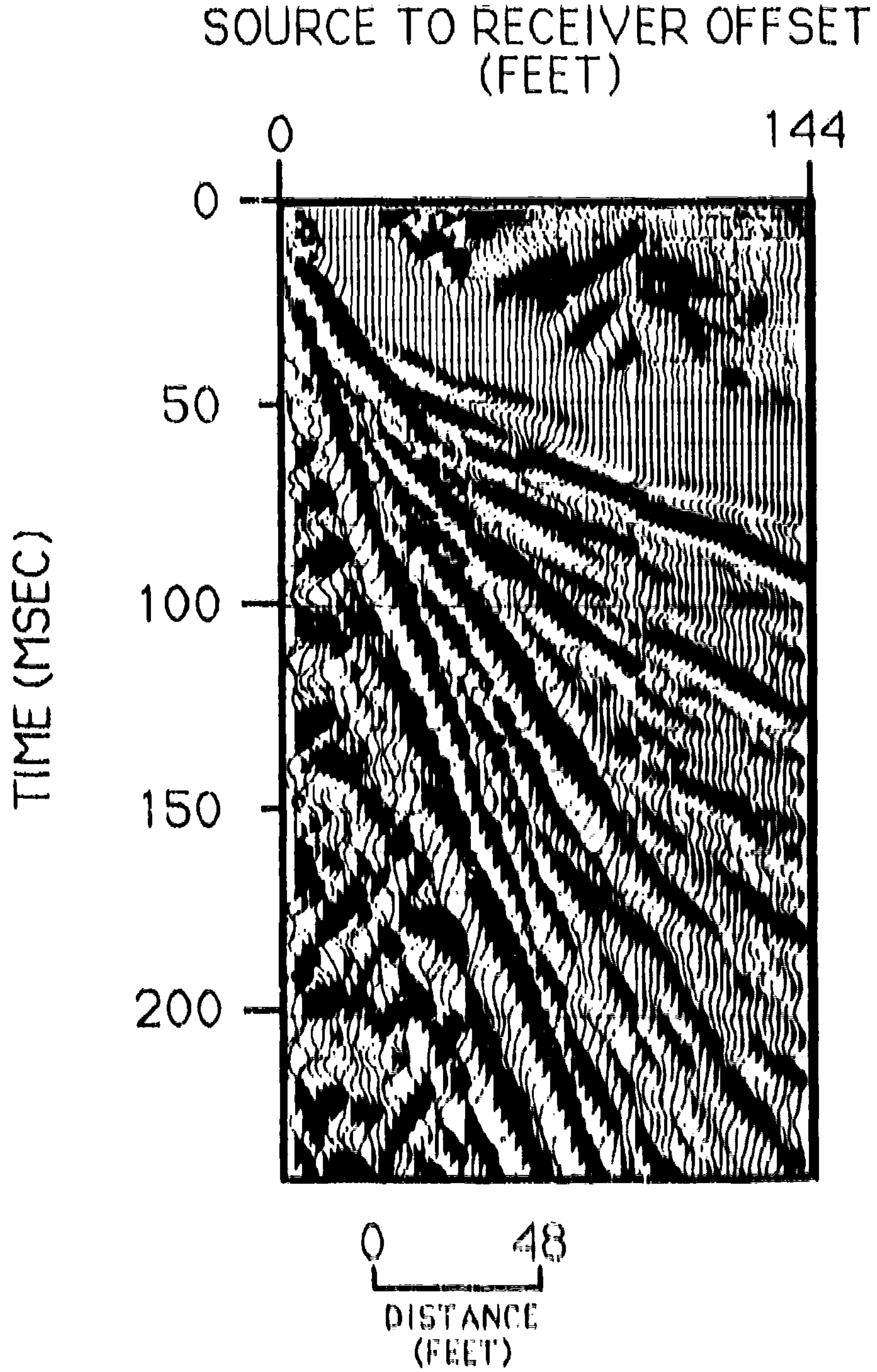
DOWNHOLE 30.06 SITE#3
128 HZ ANALOG LOWCUT FILTER



DOWNHOLE 30.06 SITE#3
4 HZ ANALOG LOWCUT FILTER

This file represents a walkaway noise test with receivers on 2 foot centers and maximum source to receiver offset of 144 ft. The source was a downhole 30.06 rifle firing a 180 grain projectile. The 4 hz lowcut filters were the lowest low cut available on the seismograph, they therefore represent lowcuts out. The geophone spread used for the walkaway test included 48 strings of 3 L-28E 40 Hz geophones wired in series and planted perpendicular the survey line. In order to obtain source receiver offsets greater than 96 ft it was necessary to move the source location. Changing the source location resulted in a slight trace to trace mismatch between files recorded with different source locations. This can be seen between receivers with offset distances of 94 ft and 96 ft on this 72 trace walkaway plot. The direct and refracted arrivals on this walkaway, as on all walkaways from this site are much more characteristic of "normal" first arrivals. The direct wave velocity at this site appears to be approximately 650 ft/sec. The apparent first refracting velocity is approximately 1800 ft/sec. As at site#1, the majority of the energy arriving within the classically quite window between the refraction and ground roll arrivals have a slope very similar to that of first arrival refraction. As well, the NMO velocity of these arrivals, clearly disqualify them from consideration as reflection energy. The energy arriving in the window most likely to possess first order reflection information is relatively broad band. The frequency band extends from about 40 hz through 350 hz. No reflection events can be confidently identified on this seismogram.

DOWNHOLE 30.06 SITE#3
4 HZ ANALOG LOWCUT FILTER



APPENDIX B

GROUND PENETRATING RADAR SURVEY, MILL CREEK DAM

Williamson and Associates
Seattle, Washington

RESULTS OF A GPR SURVEY AT THE MILL CREEK DAM, WALLA WALLA, WASHINGTON

INTRODUCTION

This report presents the results of a geophysical survey, conducted for the USACOE at Mill Creek Dam, Walla Walla, Washington. The field work, using ground penetrating radar (GPR), was performed on May 2nd and 3rd, 1989.

The objective of the survey was to detect cavities in a silt deposit which is the foundation of the dam as well as the right abutment. The silt is reported to be from 40 to 100 feet thick. Beneath the silt is a conglomerate that is approximately 100 feet thick which rests on basalt. Sinkholes have developed in the silts on the floor of the reservoir and there is concern that cavities in the silt might threaten the integrity of the dam. A suggested mechanism for cavity formation is by piping of sediments down through the rather pervious zones within the conglomerate.

GPR TECHNIQUE

The GPR produces a continuous profile of the subsurface soils and bedrock features along the survey traverse. This is accomplished by towing a radar antenna, at a walking pace, along the desired trackline. The antenna is connected by a 40 meter cable to a processor and display recorder mounted in the field vehicle (Figure 1). During the traverse, the antenna alternately transmits and receives high frequency (120 MHz) radar pulses. The received pulses, which represent reflections from subsurface features are immediately processed and displayed on the graphic recorder. Since this transmit/receive process occurs at such a high rate, a vertical profile or "sounding" is obtained for each 4 inches of horizontal travel along the survey transect.

The resulting display is a continuous subsurface profile providing detailed information on subsurface features. Those features on the radargram that represent soil horizons or stratigraphic layers are produced by changes in the conductivity between adjacent layers of soil. Typically these variations can be associated with changes in lithology, an increase in moisture content, or contaminants having electrical conductivity properties different than

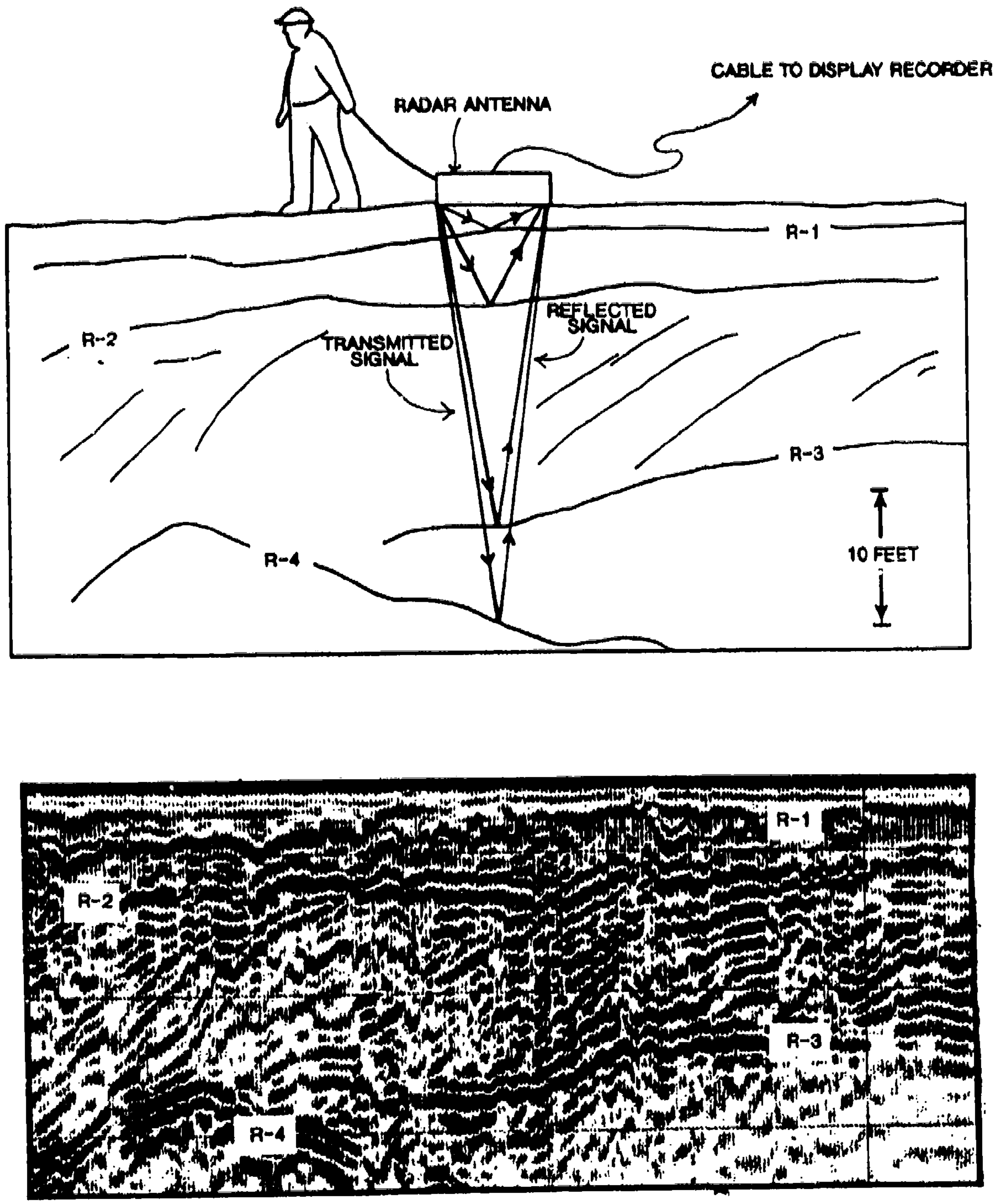


Figure 1 Illustration of GPR technique and radargram.

those of water. In addition, reflections can be produced by: subtle variations in the geologic structure and fabric such as fractures, faulting and subsurface voids.

FIELD PROCEDURES

The survey was performed with a GSSI System 3 ground penetrating radar (GPR) system using a 120 MHz antenna. Data was collected along four primary survey lines, selected by the ACOE, and around an existing sinkhole in the bottom of the reservoir. Several runs were made along each line with the display recorder set for different scales on each run in an attempt to maximize the depth of penetration or the near surface resolution. A 150 nanosecond scale was used to provide detailed information on the near surface stratigraphy in the area of the sinkhole while a 300 nanosecond scale was used to map deeper subsurface features on lines C, D, E & F. These time scales represent a depth scale of approximately 30 feet and 60 feet.

The antenna was pulled by hand along each of the survey lines that had been previously laid out and staked by the ACOE. As the antenna was pulled past each stake (20 foot intervals) a control or position mark was placed on the radargram. Final position of the lines and horizontal control was provided by the ACOE for the final report.

Field notes describing the general condition of the ground surface, such as major topographic changes, the presence of cultural features or waste materials, and the type of surficial soils were kept during the survey. This information used was to assist in analyzing the GPR data.

DATA ANAYSIS AND INTERPRETATION:

The areas surveyed with the GPR are plotted on Plate 1 which shows both the tracklines and the location of subsurface anomalies. The anomaly numbers on this plate correspond with the numbers shown on the radargrams located in the appendix. A brief discussion of the subsurface geology and significant features is presented in the following table.

LINE C

GPR Anomaly Number	Description
General	Thin surface layer (1 to 3 feet thick) along entire survey line. Below this reflector materials are homogeneous with only an occassional subsurface reflector.
C-42	Subsurface ringing from -2 feet to -10 feet
C-49 to C-63	Shallow subsurface depression
C-60	Small diffractions at -17 feet, some shallower reflectors.

LINE D

GPR Anomaly Number	Description
General	Thin surface layer (1 to 3 feet thick) and very homogenous and uniform subsurface materials.
D-51 to D-53	Small subsurface depression

LINE E

GPR Anomaly Number	Description
General	Thin surface layer (1 to 3 feet thick) and homogenous subsurface sediments.
C-16	Small diffraction 2 feet below the ground surface.

LINE F

GPR Anomaly Number	Description
General	Thin surface layer (1 to 3 feet thick) and homogenous subsurface sediments.
F-14	Diffraction at 5 feet below ground surface and some ringing and reflectors at -20 feet.

SINK HOLE SURVEY: LINES 1-5

GPR Anomaly Number	Description
General	Series of NS lines centered on sink hole. Lines 1 and 2 show generally flatlying surface layer with homogenous subsurface stratigraphy. On lines 3, 4 and 5 a subsurface reflector can be seen dipping to the south towards the dam. The first deflection or rollover occurs at the sink hole.

SINK HOLE SURVEY: LINES 6-10

General	Series of EW lines centered on the sink hole and oriented at right angles to line 1-5. On lines 6,7 and 8 a pronounced subsurface escarpment occurs approximately 50 feet from the start of the line. This is nearly centered on the sink hole and the NS line number 3 (Lines 6.5 and 7.5 divide these lines). East of this hinge line high amplitude subsurface reflectors can be mapped to a depth of -15 feet. On line 9 and 10 a shallow subsurface depression, centered on line 3, extends entirely across the survey area. On line 10, deeper reflectors (-10 to -15 feet) below this depression indicate the presence of a narrow basin. On line 9 a small subsurface diffraction can be seen between cross lines 1 and 2 at approximately 5 feet below the ground surface.

SUMMARY AND CONCLUSIONS

Ground penetrating radar was successfully used to map the subsurface soil characteristics along 4 transects and in the vicinity of a sink hole at the Mill Creek Reservoir. The following summarizes the results of this survey.

* In general the subsurface soils along the primary survey lines (Lines C, D, E, & F) were quite homogenous and uniform. There were occassional subsurface anomalies but the data does not clearly indicate that these features on the radargram are subsurface voids or pathways for water migration.

* In the sinkhole area several features or anomalies on the radargram are suggestive of possible subsurface voids or migration pathways. On line 9, the small hyperbolic feature between cross lines 1 and 2 is a typical signature of a void like feature. On line 10 the deeper subsurface depression, between cross lines 3 and 4, is possible evidence for a zone of subsurface migration.

* There is no surface express of the steep subsurface escarpment that is in alignment with the sinkhole. Although this alignment may be coincidental, several small hyperbolic reflectors beneath the toe of the escarpment and the increase in apparent reflectivity suggests that this is possibly an area of groundwater leakage and piping of sediment.

* There was no evidence of conglomerates or bedrock on the radargrams.

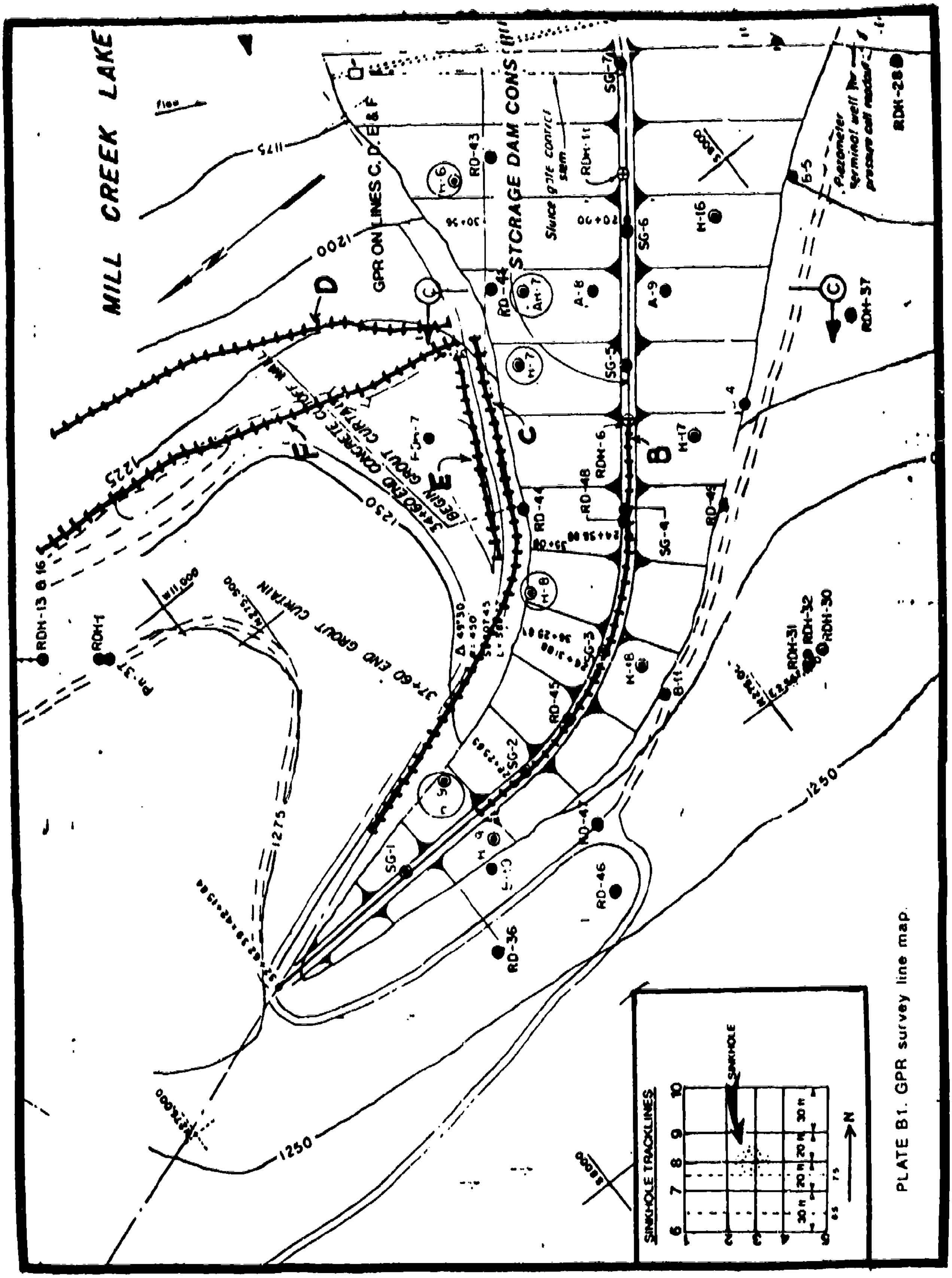
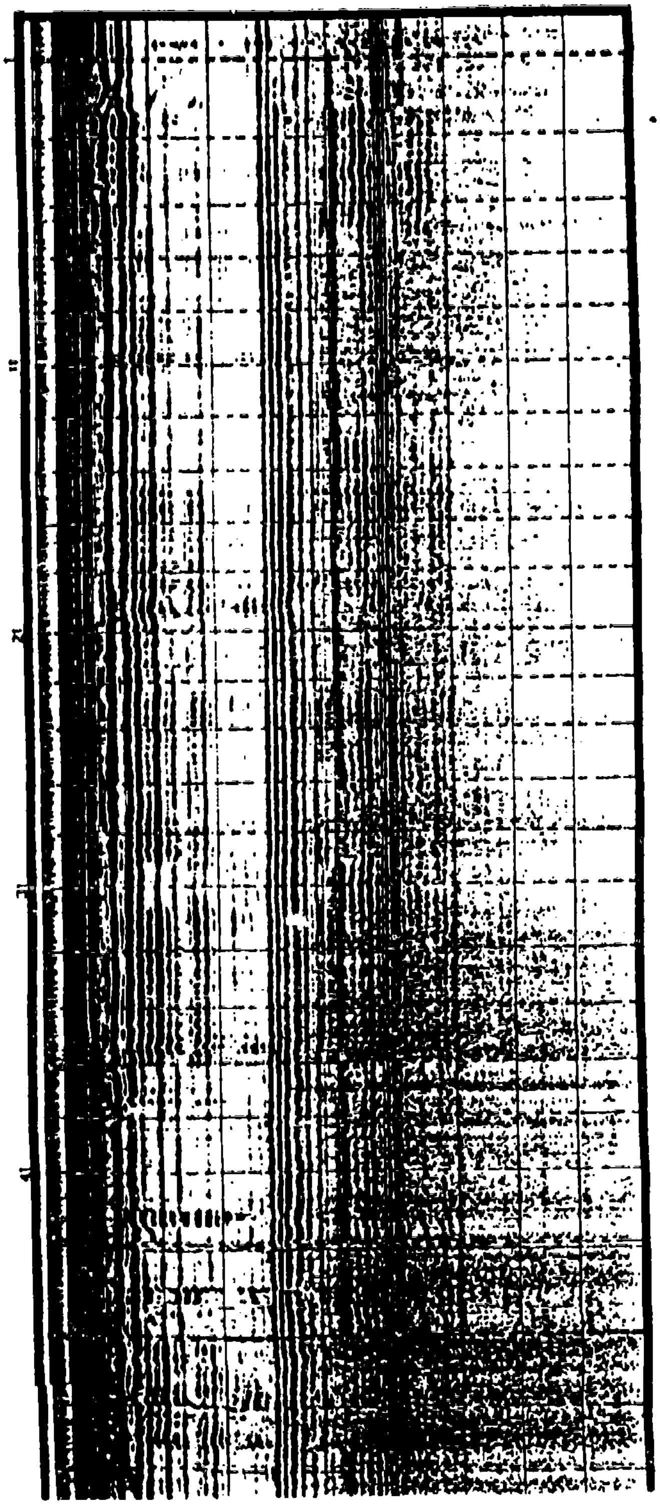
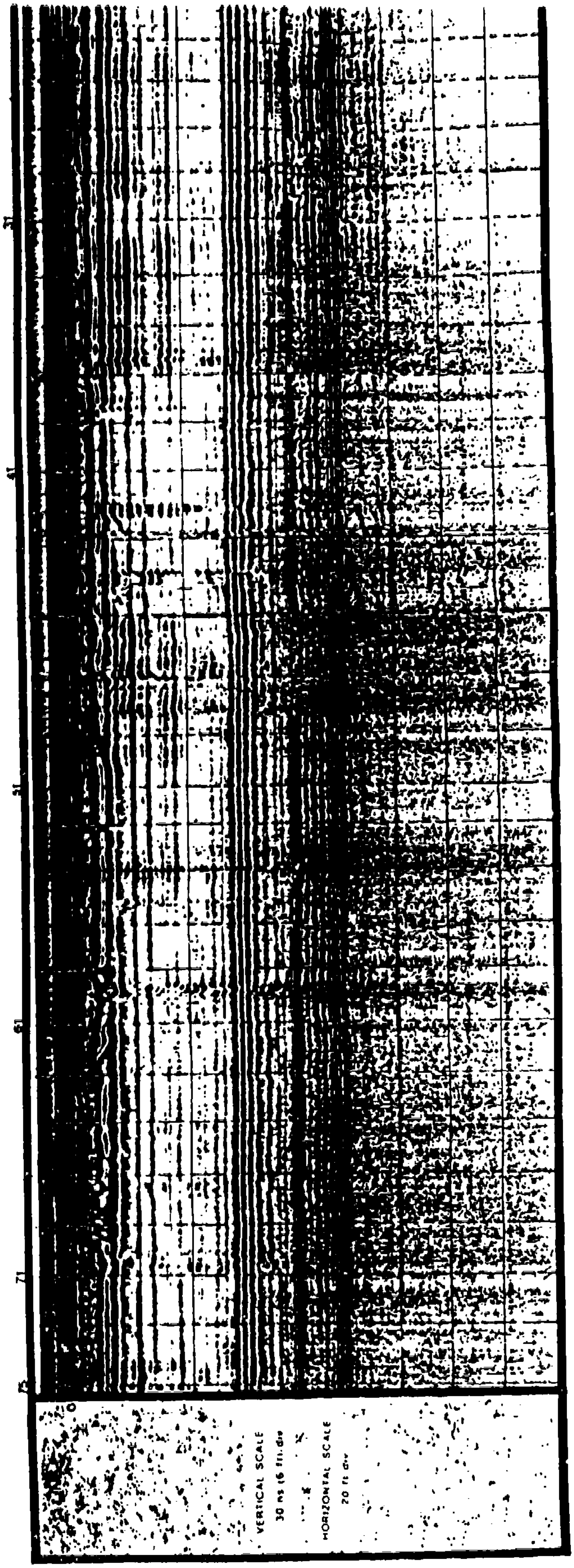
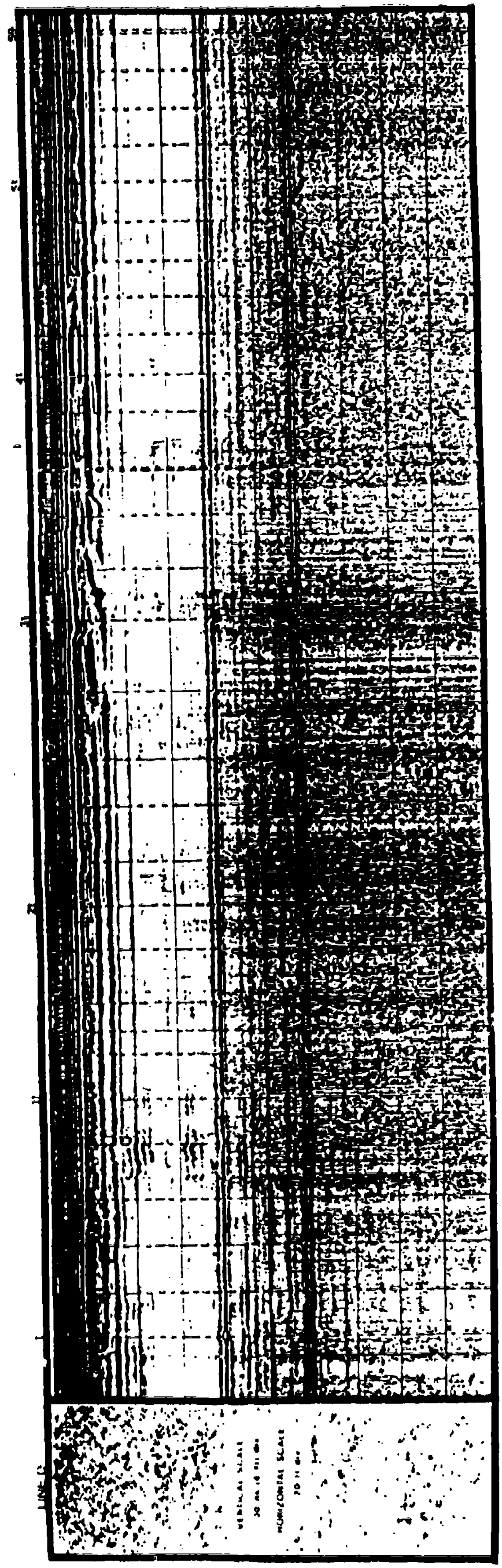


PLATE B1. GPR survey line map.




VERTICAL SCALE
HORIZONTAL SCALE
20 ft div


VERTICAL SCALE
HORIZONTAL SCALE

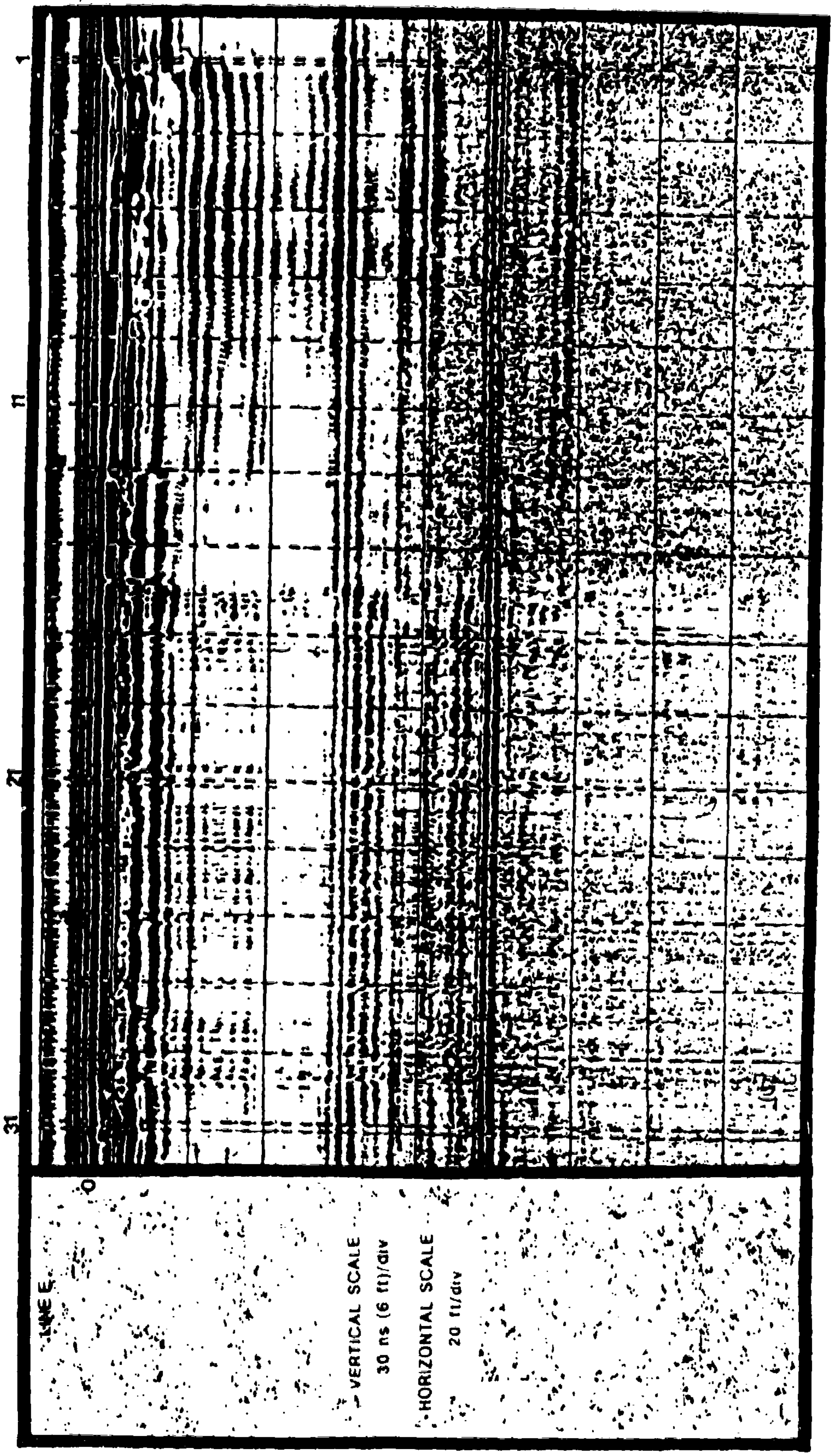
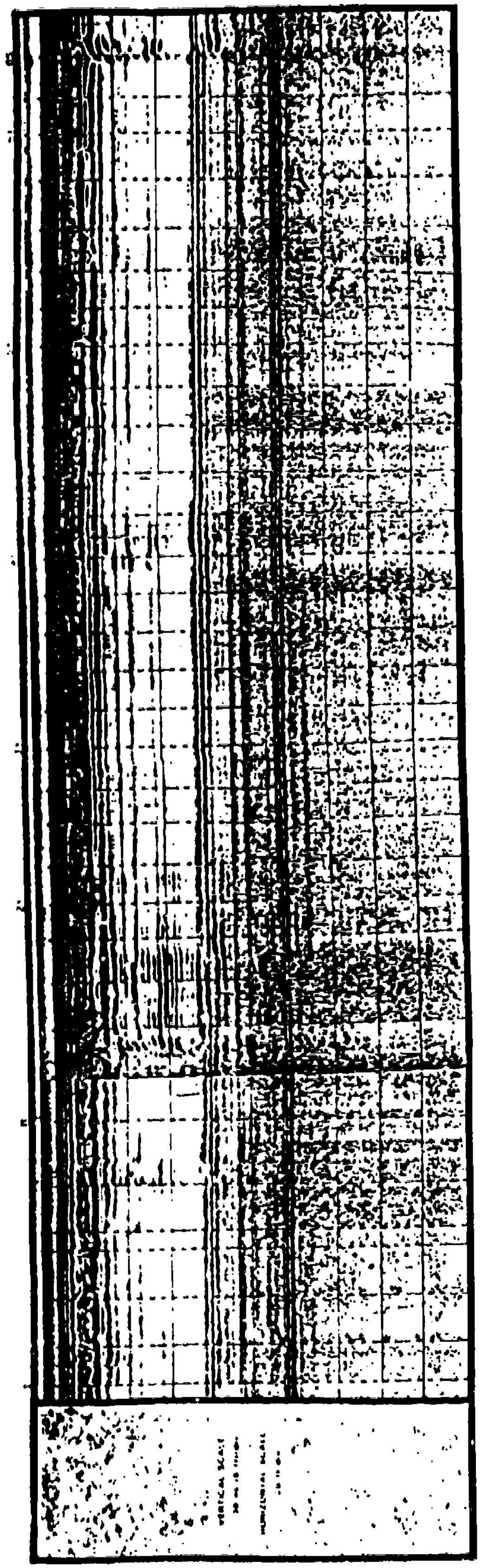


PLATE B4 Line E



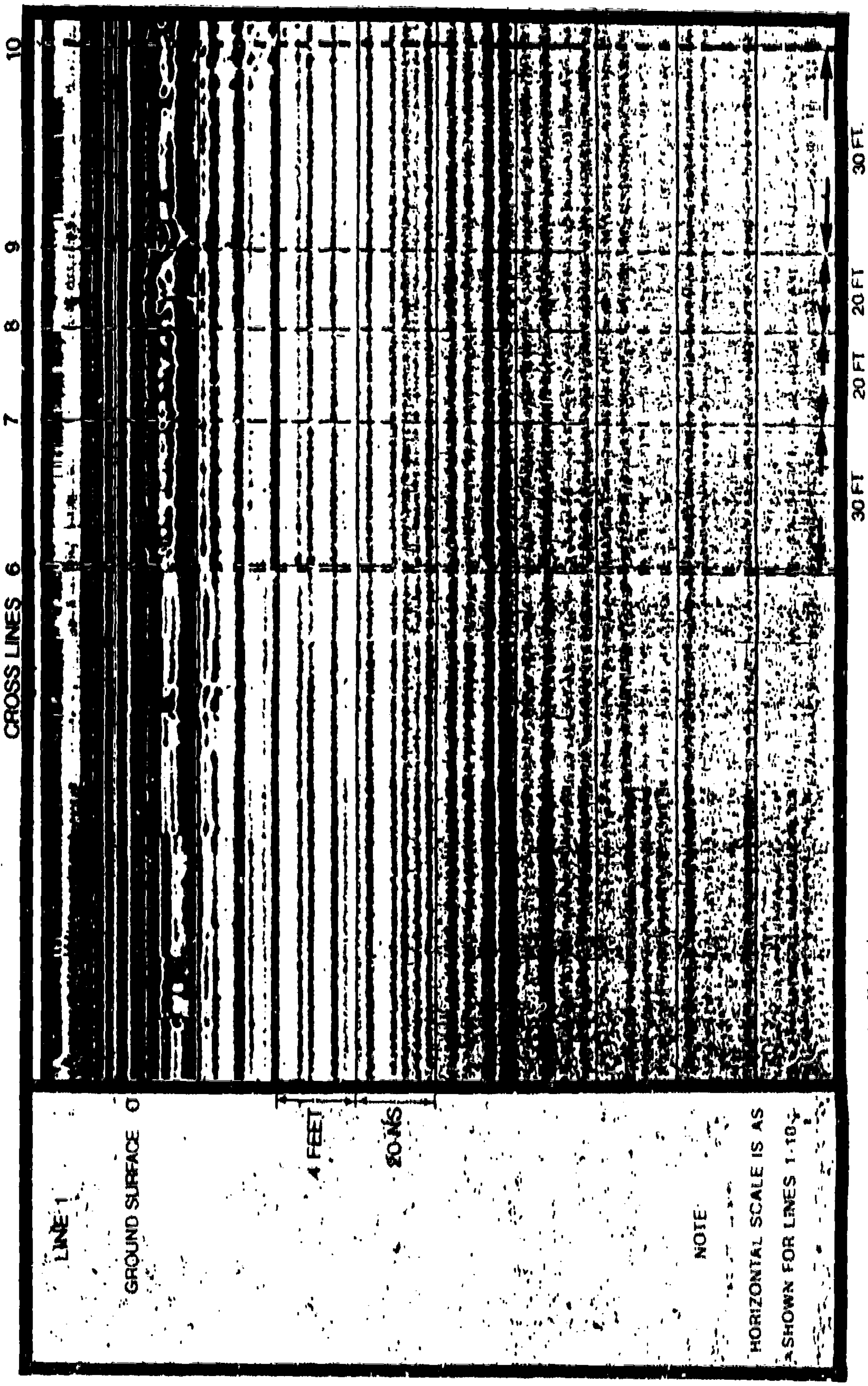
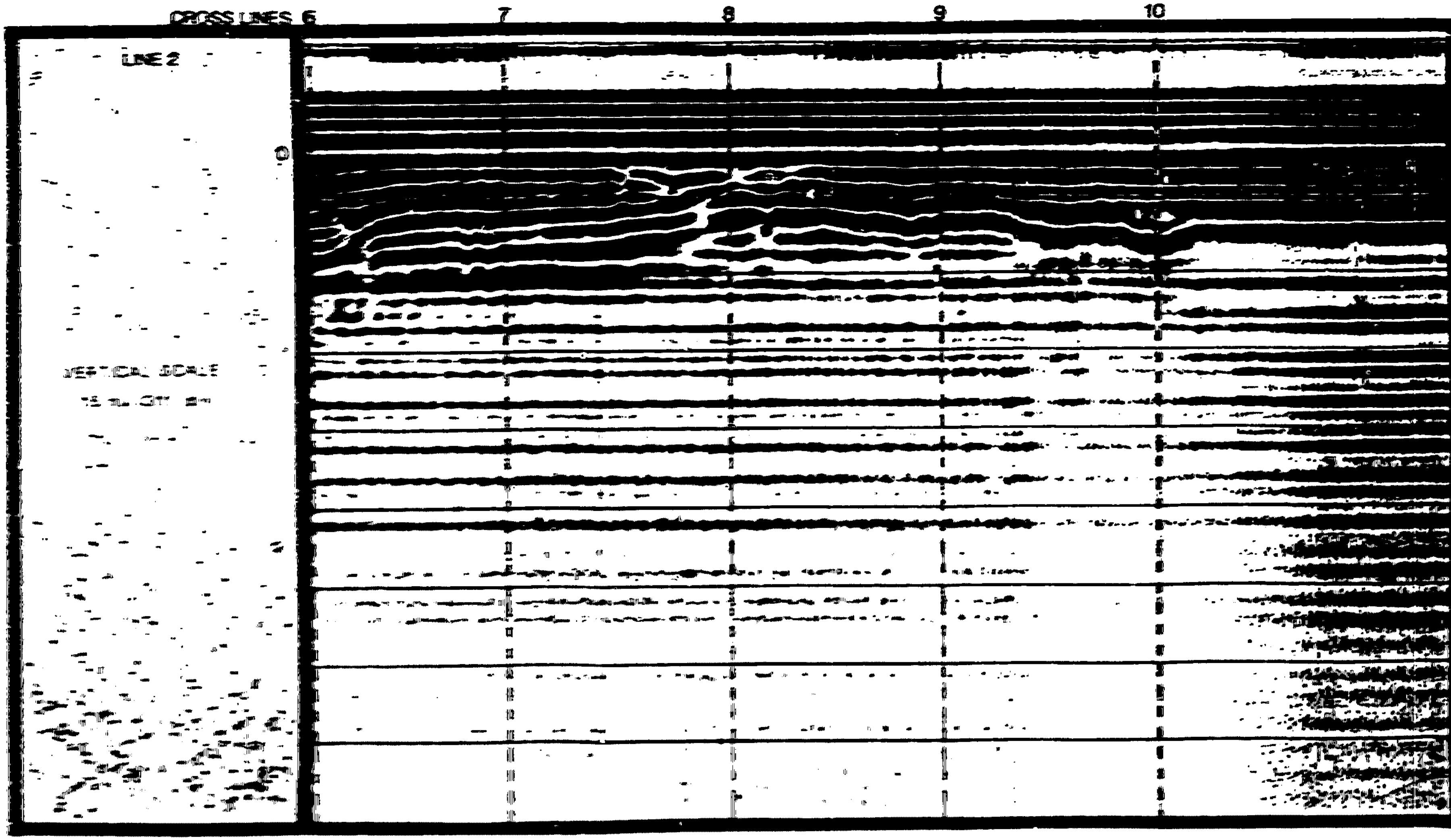


PLATE B6 Substrate line 1


CROSS LINES 6
7
8
9
10
LINE 2
VERTICAL SCALE

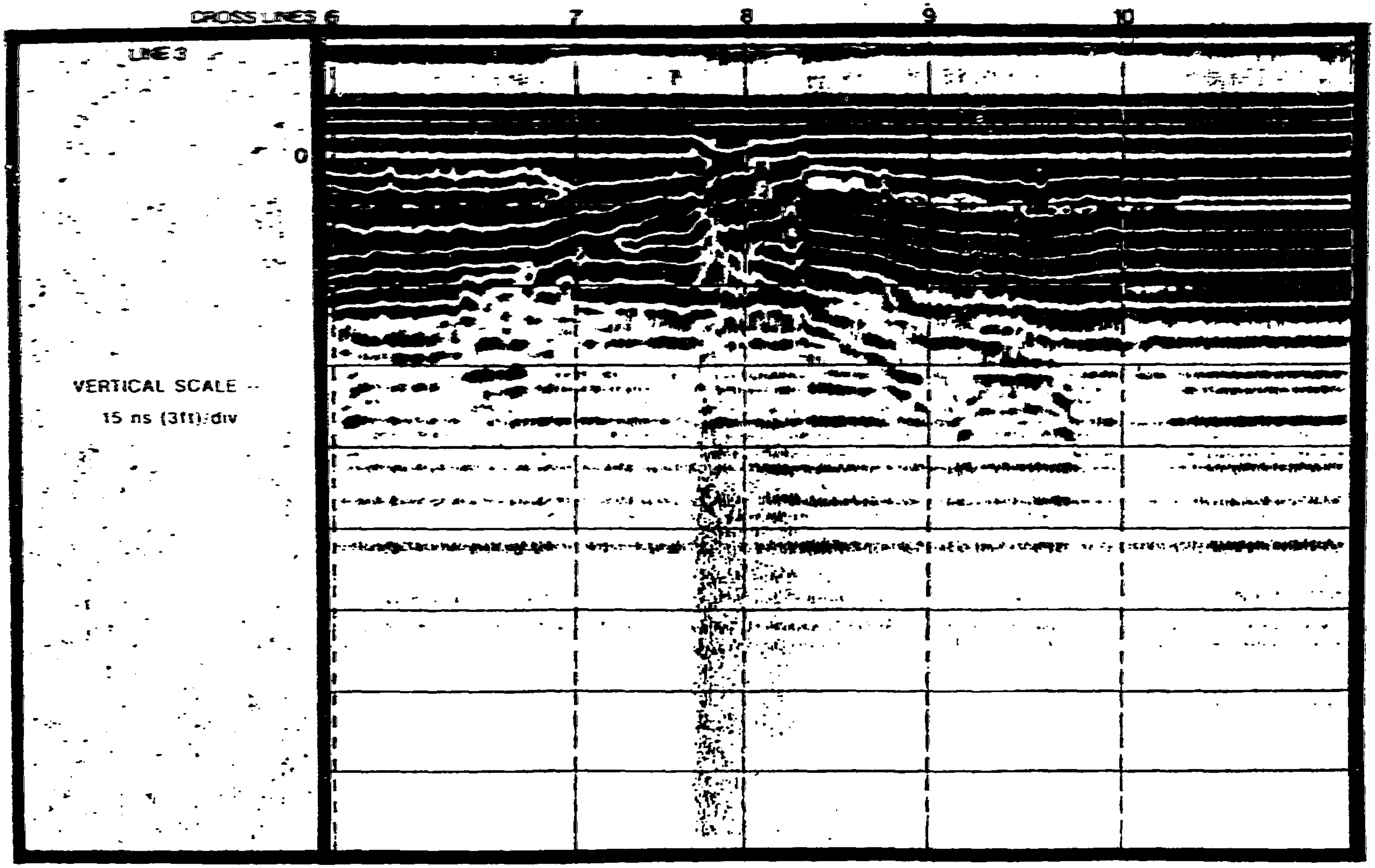


PLATE B8 Sinkhole line 3.

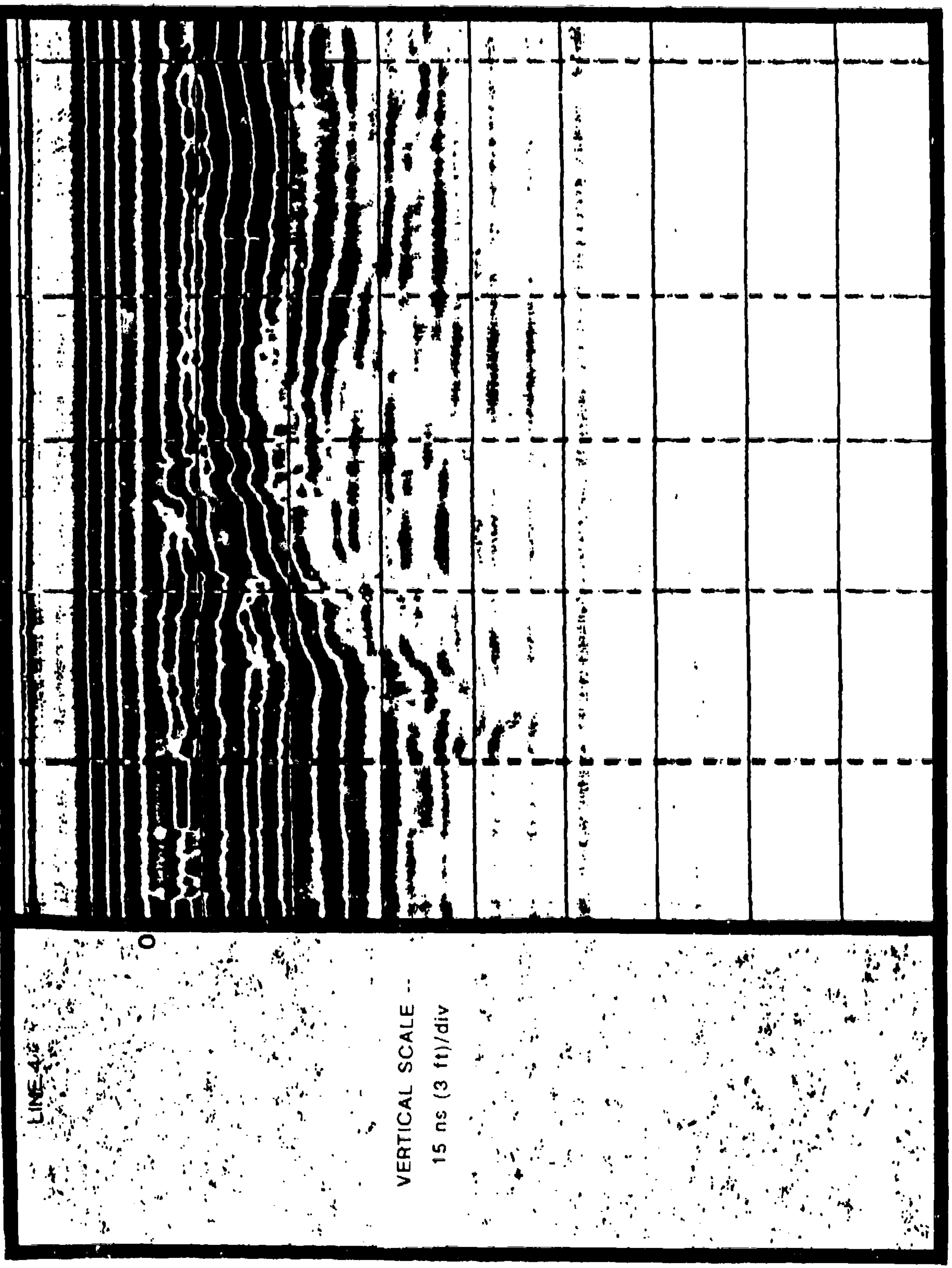


PLATE B9 Sinkhole line 4.

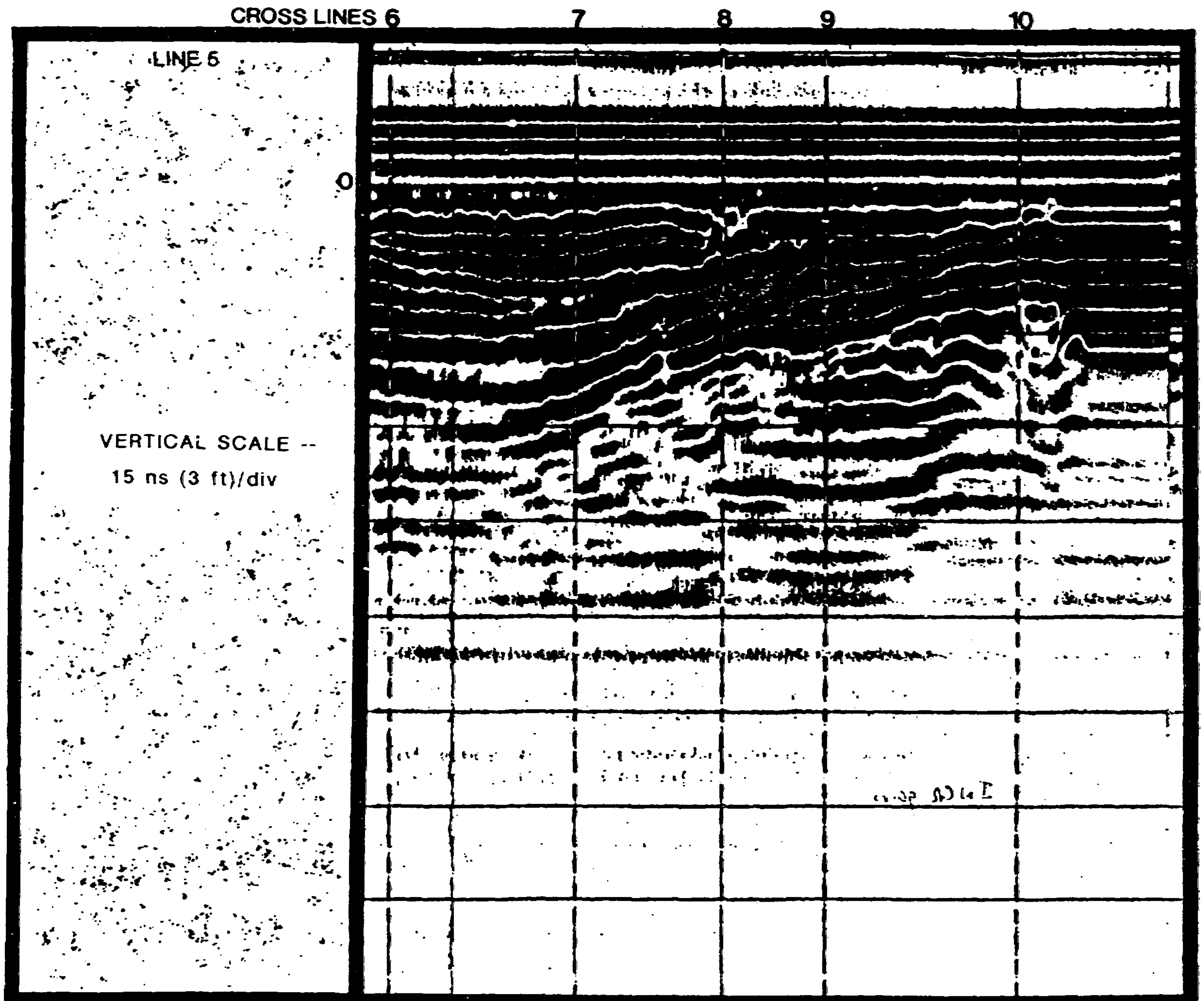


PLATE B10. Sinkhole line 5.

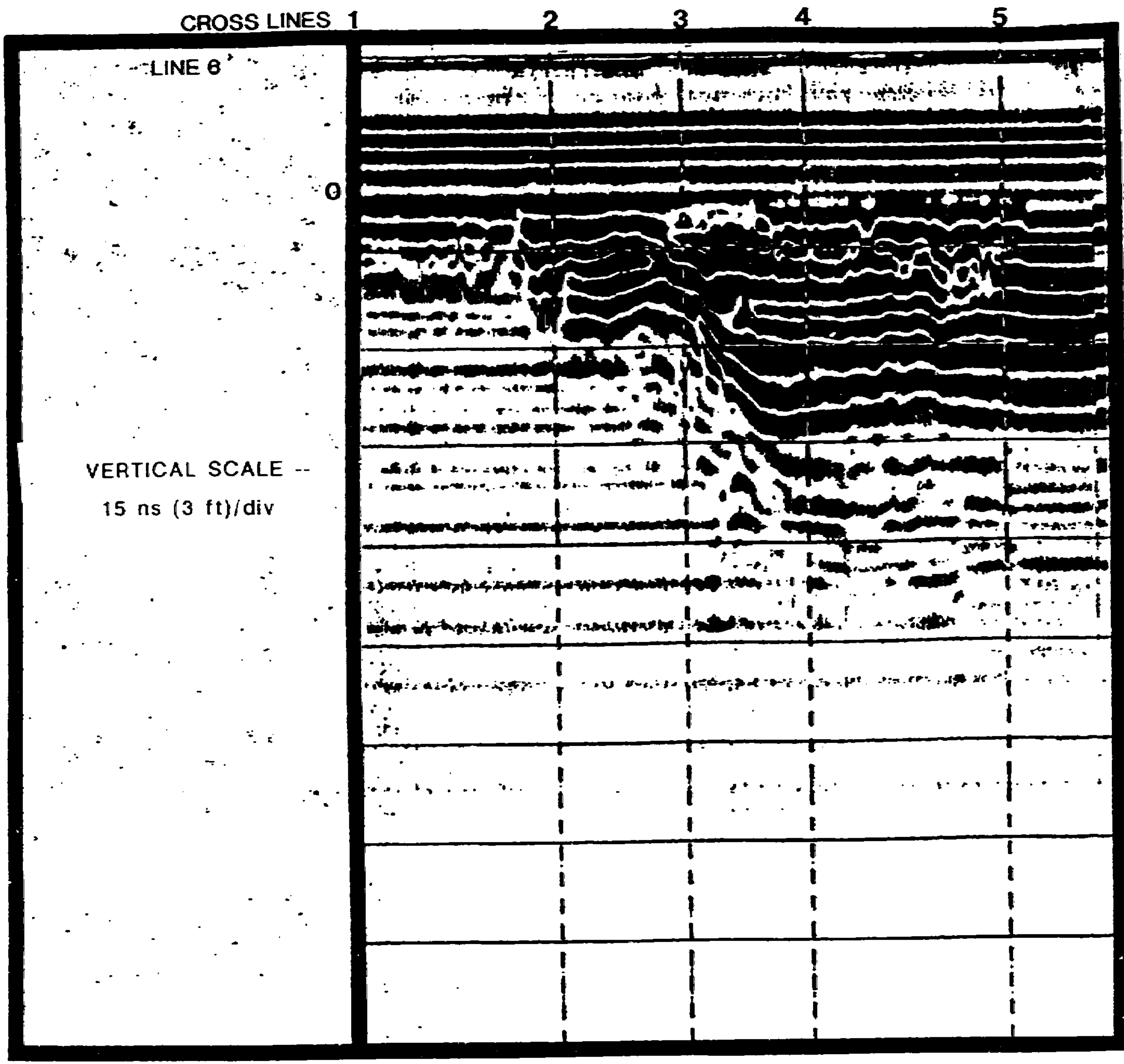


PLATE B11. Sinkhole line 6.

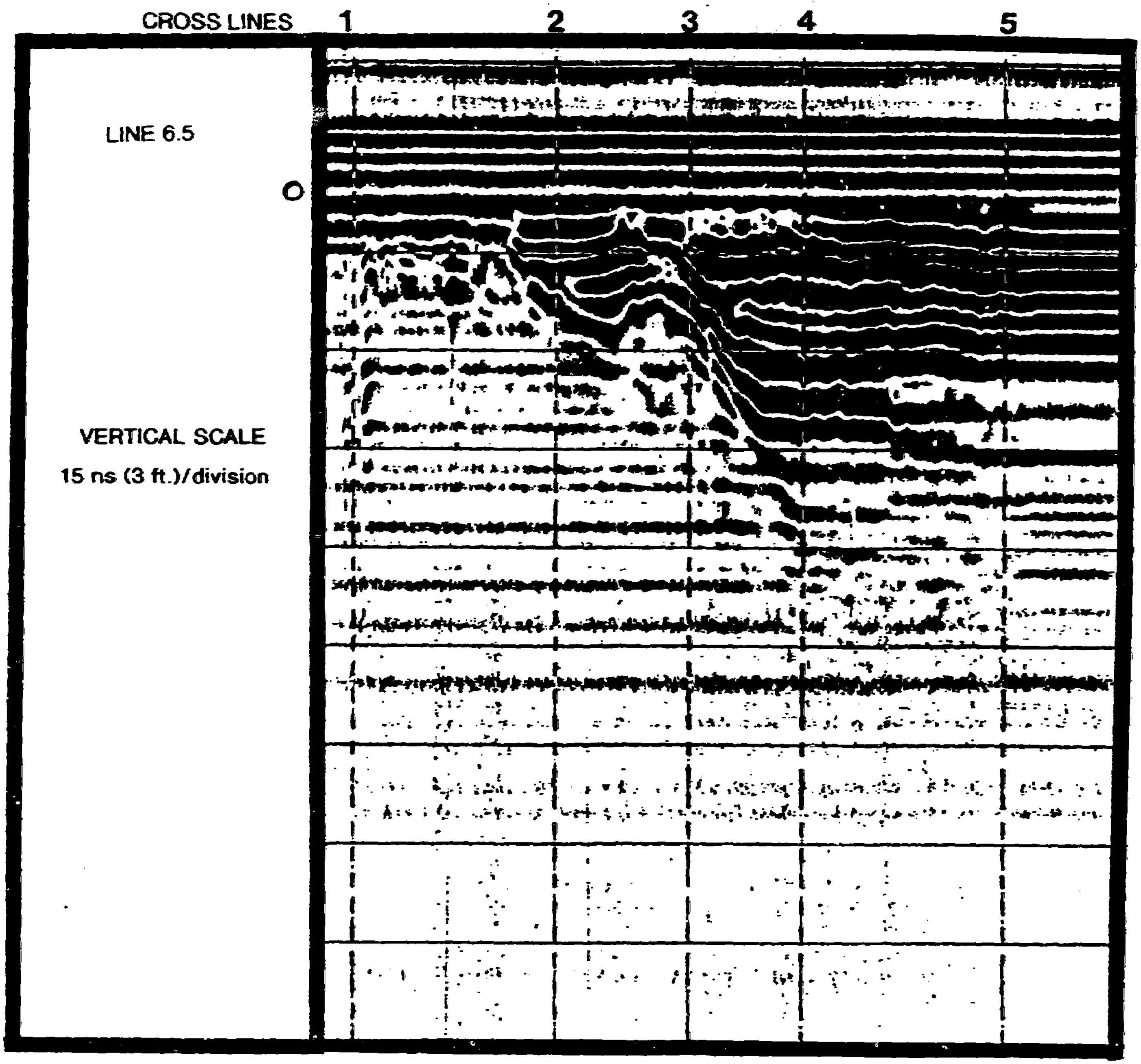


PLATE B12. Sinkhole line 6.5.

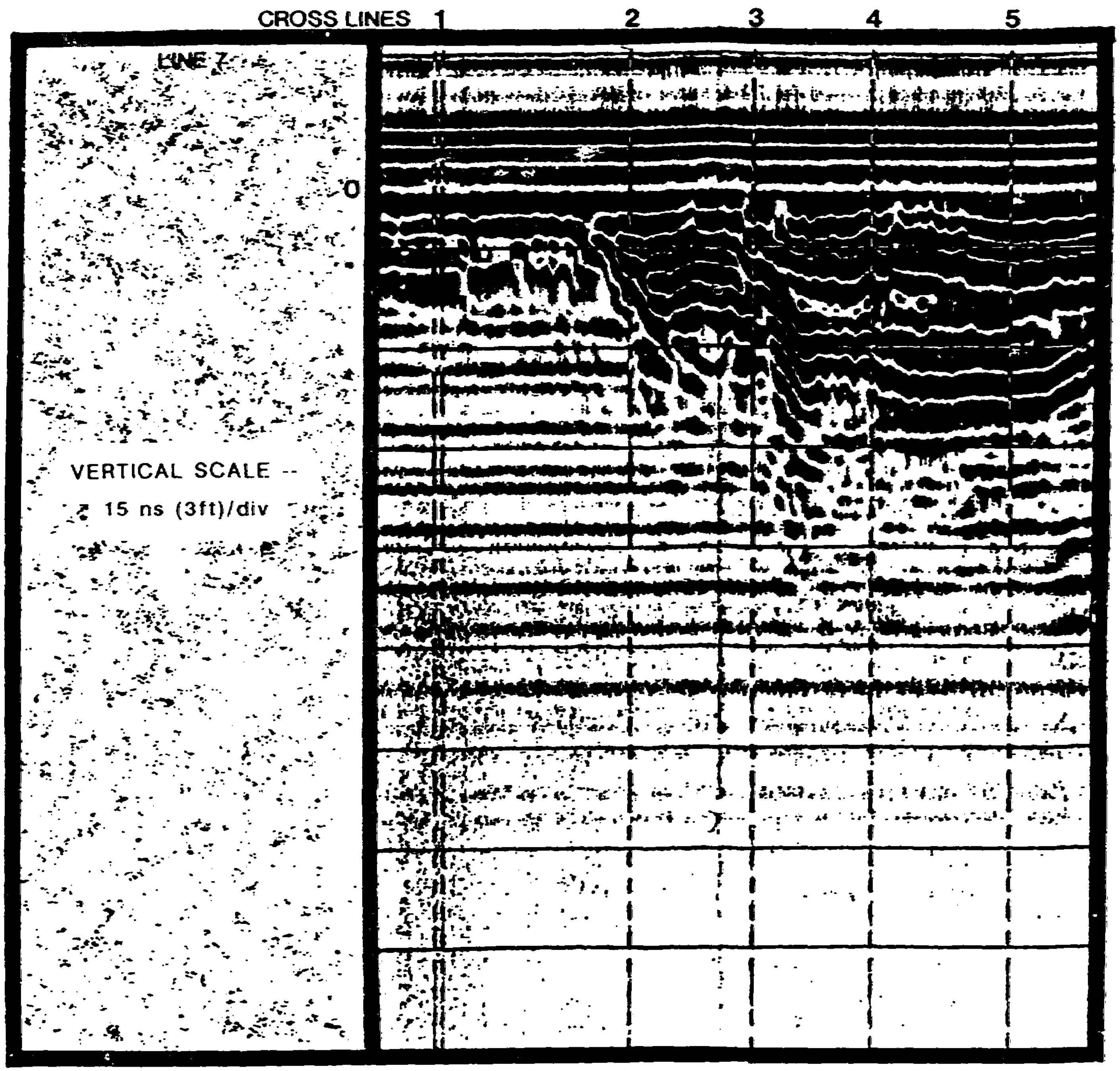


PLATE B13. Sinkhole line 7

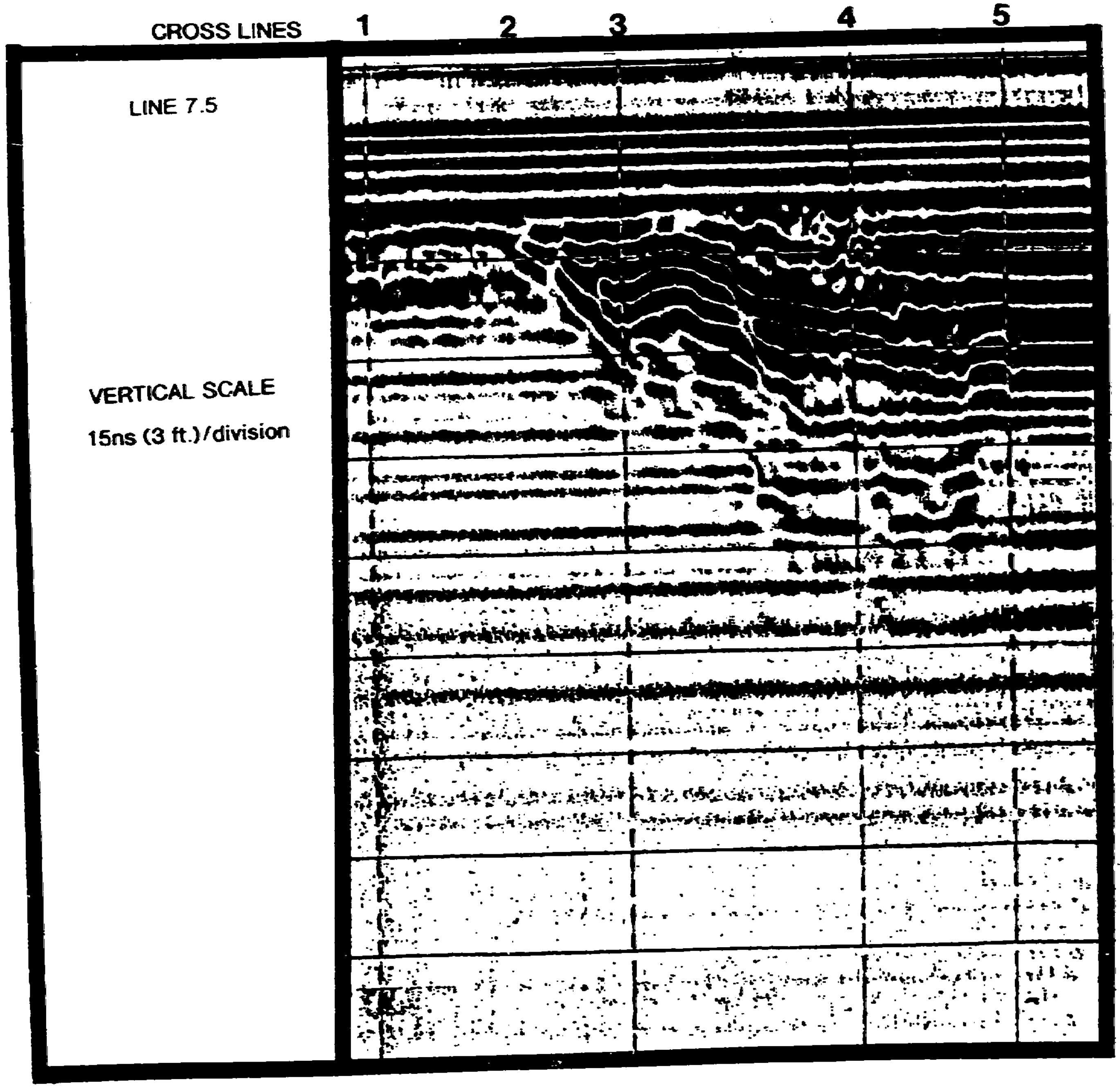


PLATE B14. Sinkhole line 7.5.

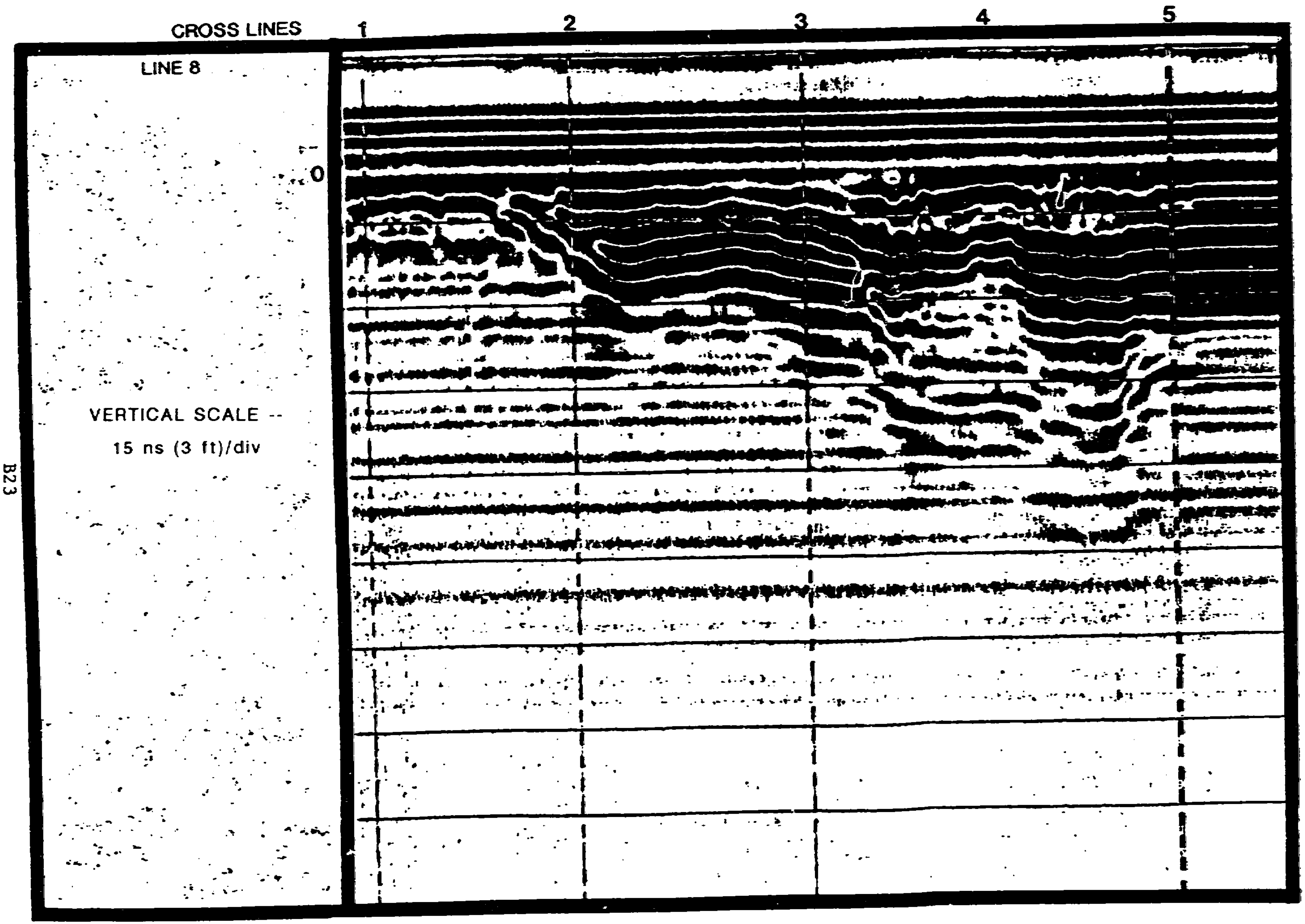


PLATE B15. Sinkhole line 8.

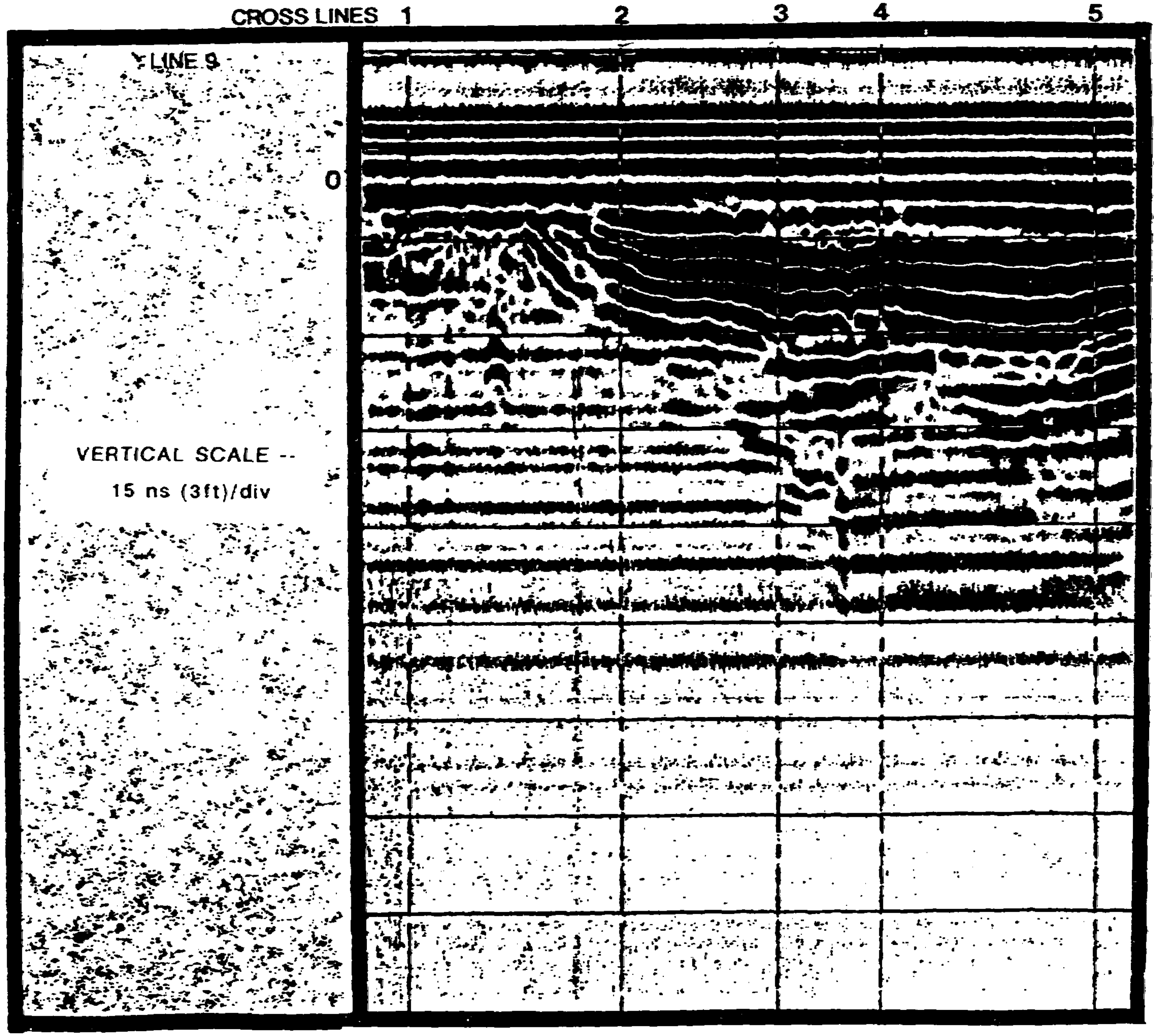


PLATE B16 Sinkhole line 9.

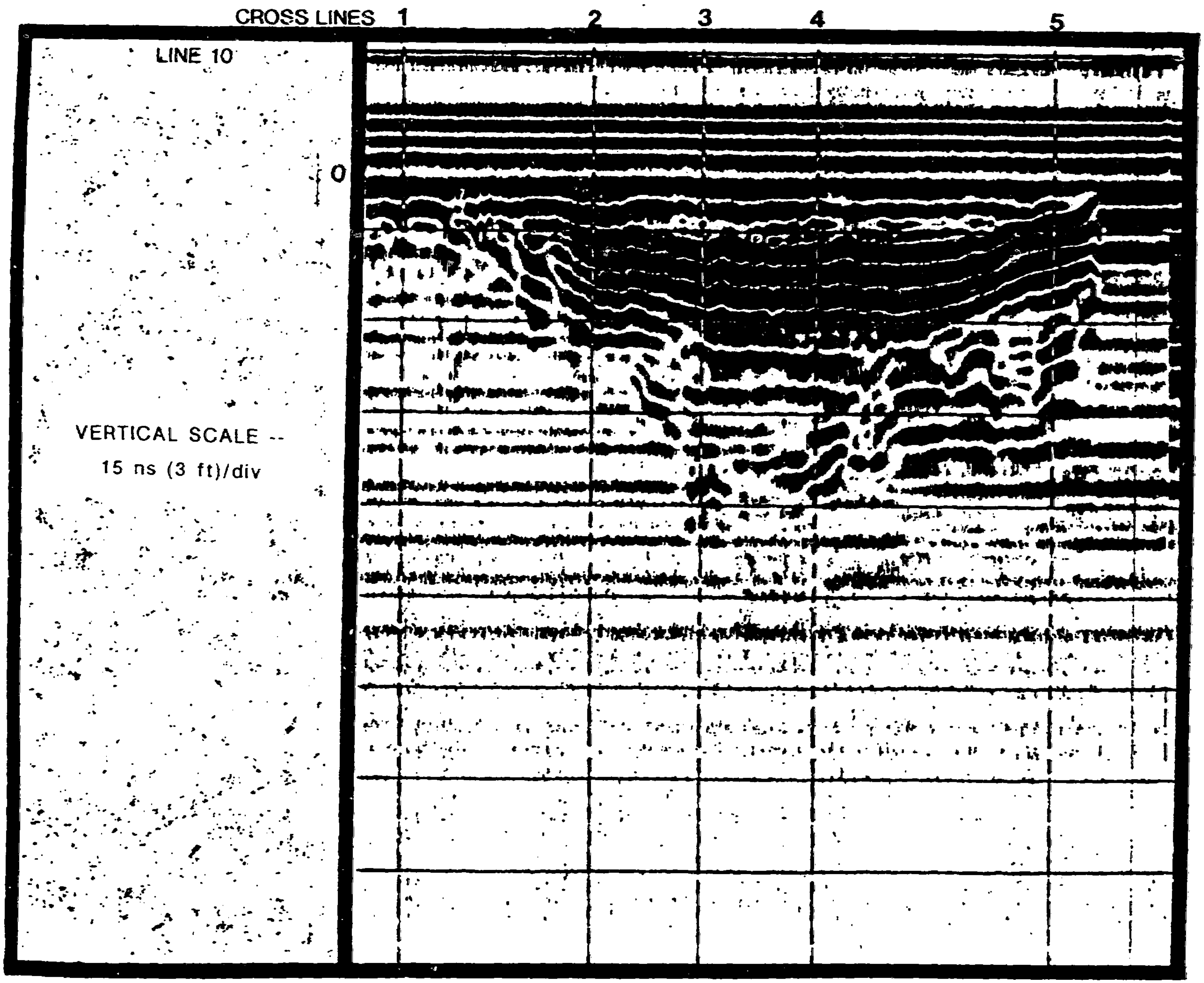


PLATE B17. Sinkhole line 10.

APPENDIX C

POLE-DIPOLE RESISTIVITY SOUNDING PLOTS

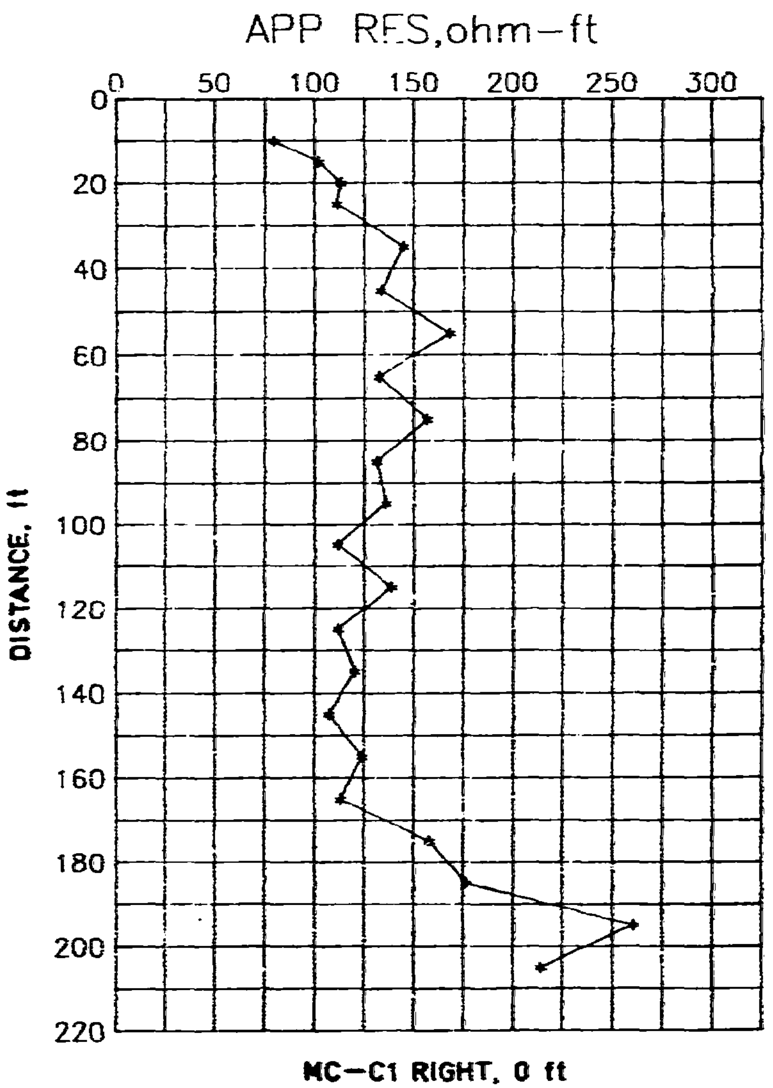


Figure C1. Pole-dipole survey, line C, 0 ft, right, 'raw' data plot.

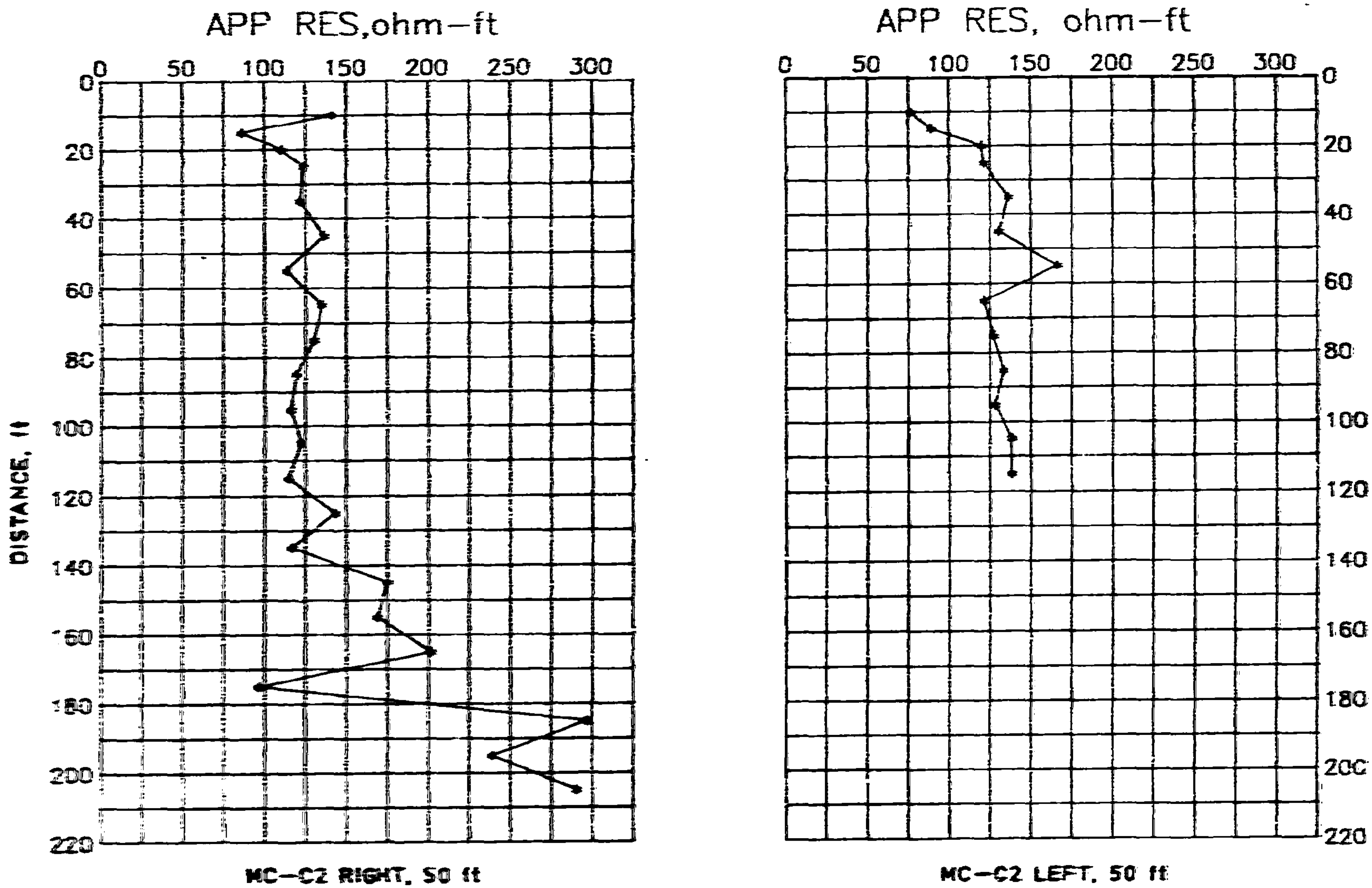
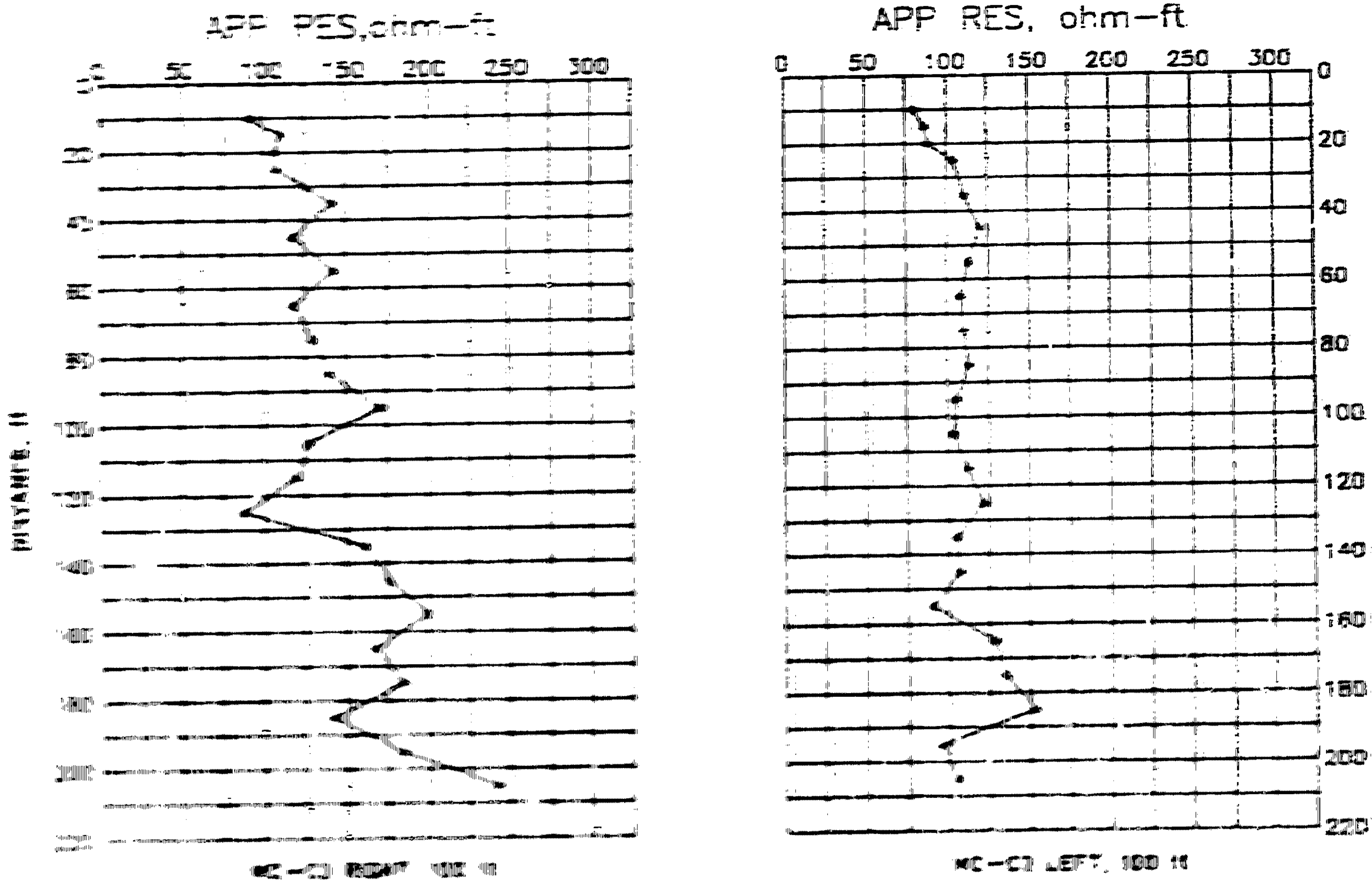


Figure C2. Pole-dipole survey. line C. 50 ft. right/left, 'raw' data plot.


APP RES, ohm-ft
0
50
100
150
200
250
300
0
20
40
60
80
100
120
140
160
180
200
220

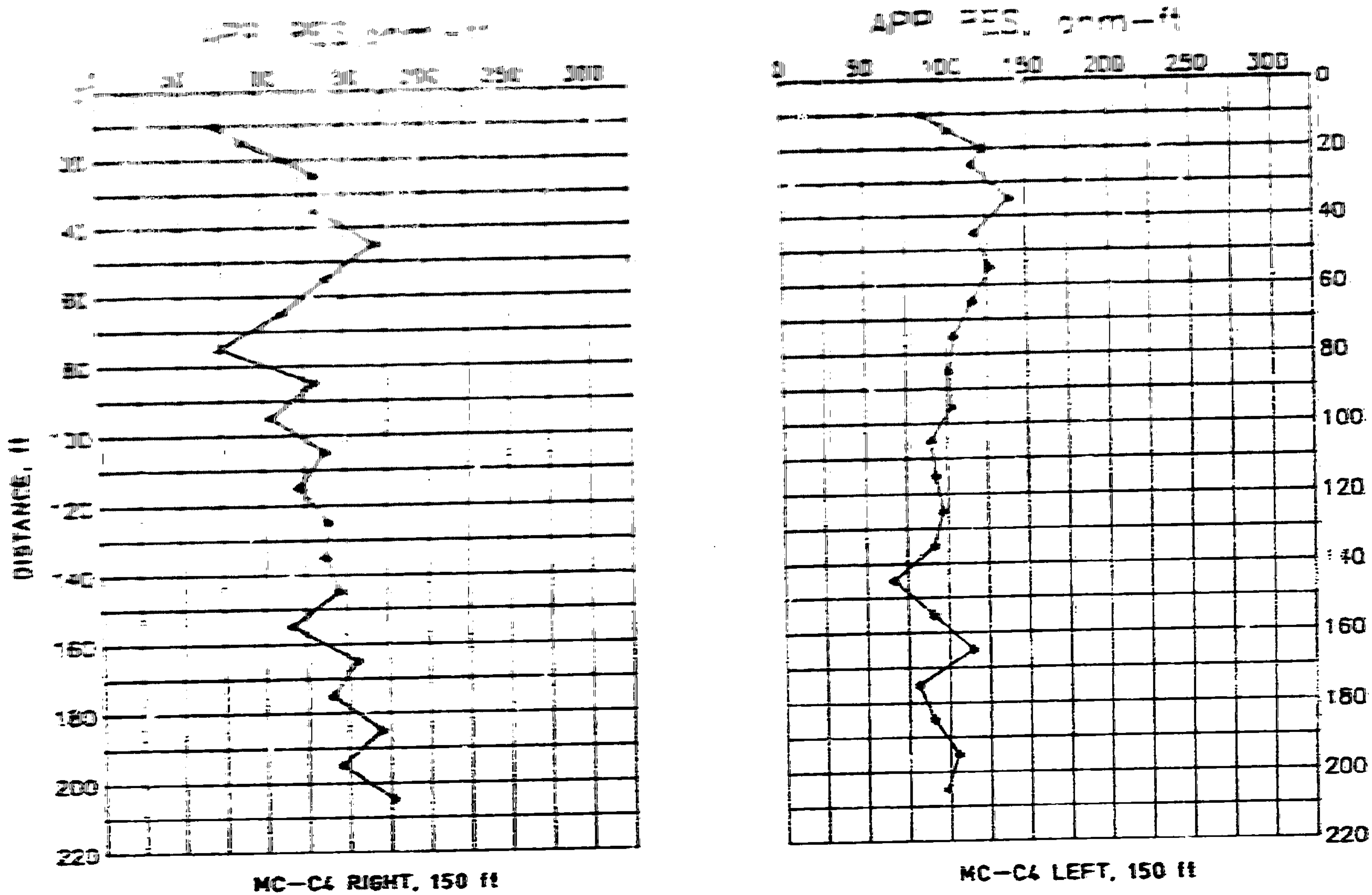


Figure C4. Pole-dipole survey, line C, 150 ft, right/left, 'raw' data plot.

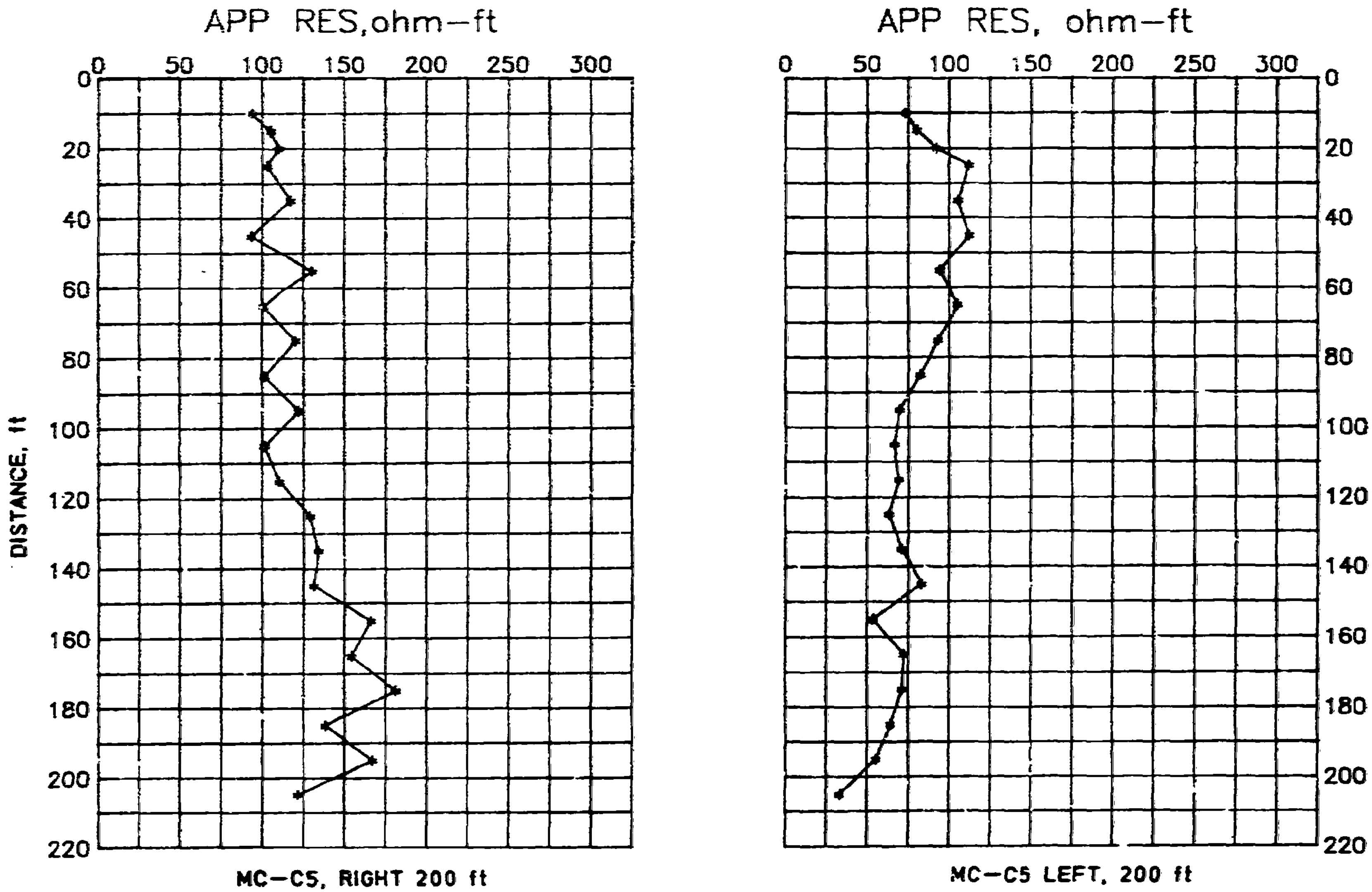


Figure C5. Pole-dipole survey, line C. 200 ft, right/left. 'raw' data plot.

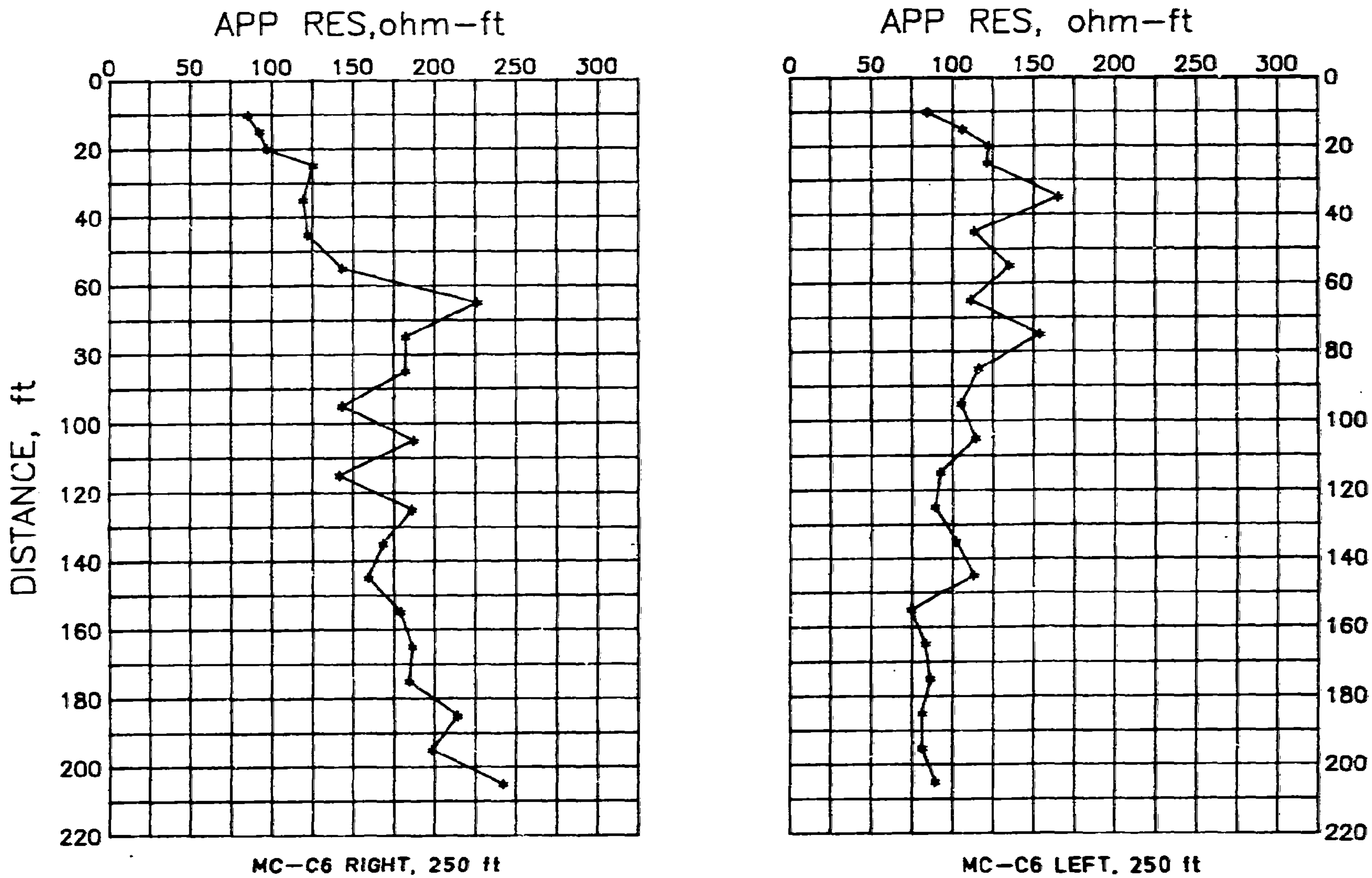


Figure C 6. Pole-dipole survey, line C. 250 ft, right/left. 'raw' data plot.

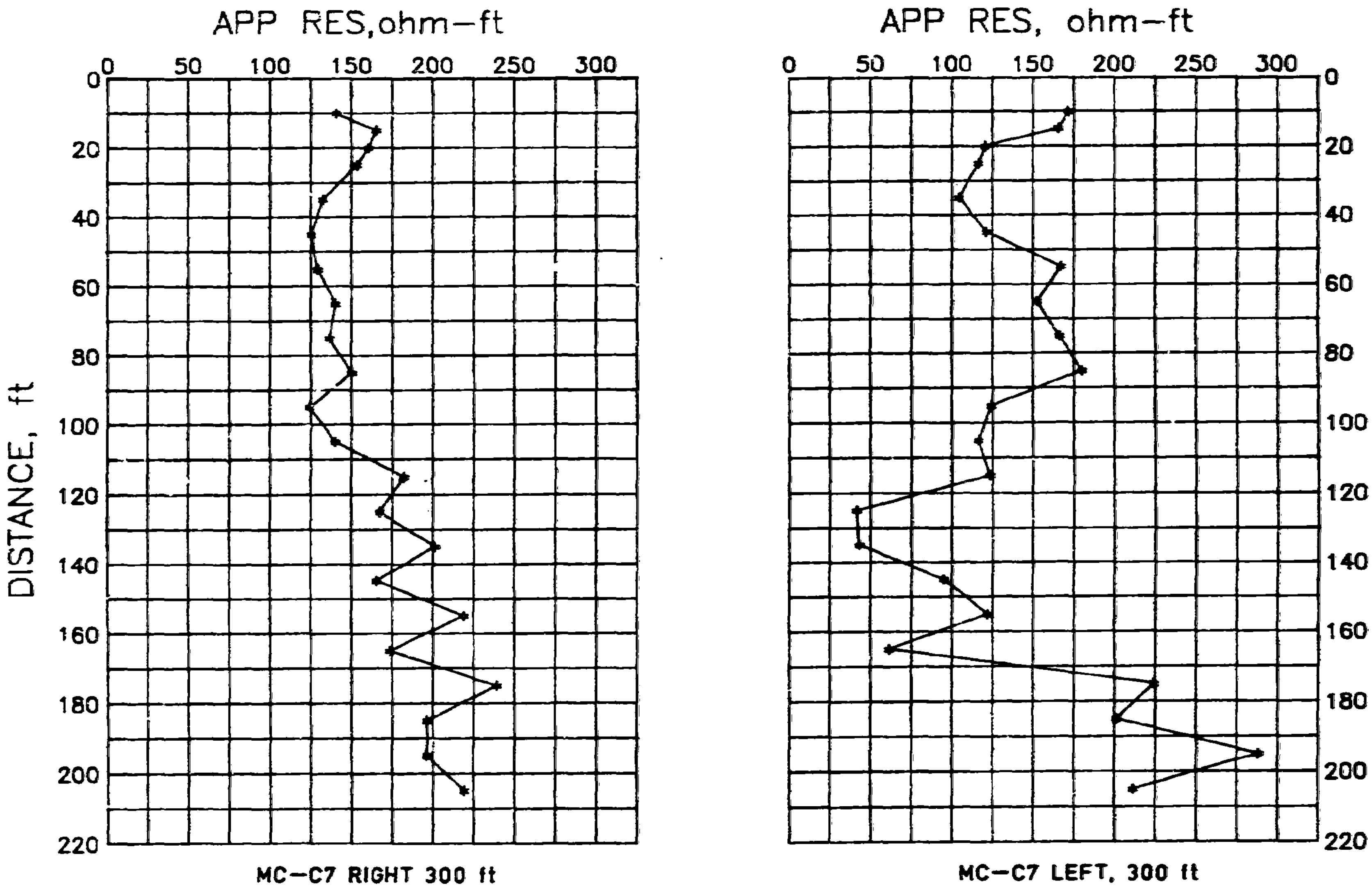


Figure C7. Pole-dipole survey, line C. 300 ft, right/left, 'raw' data plot.

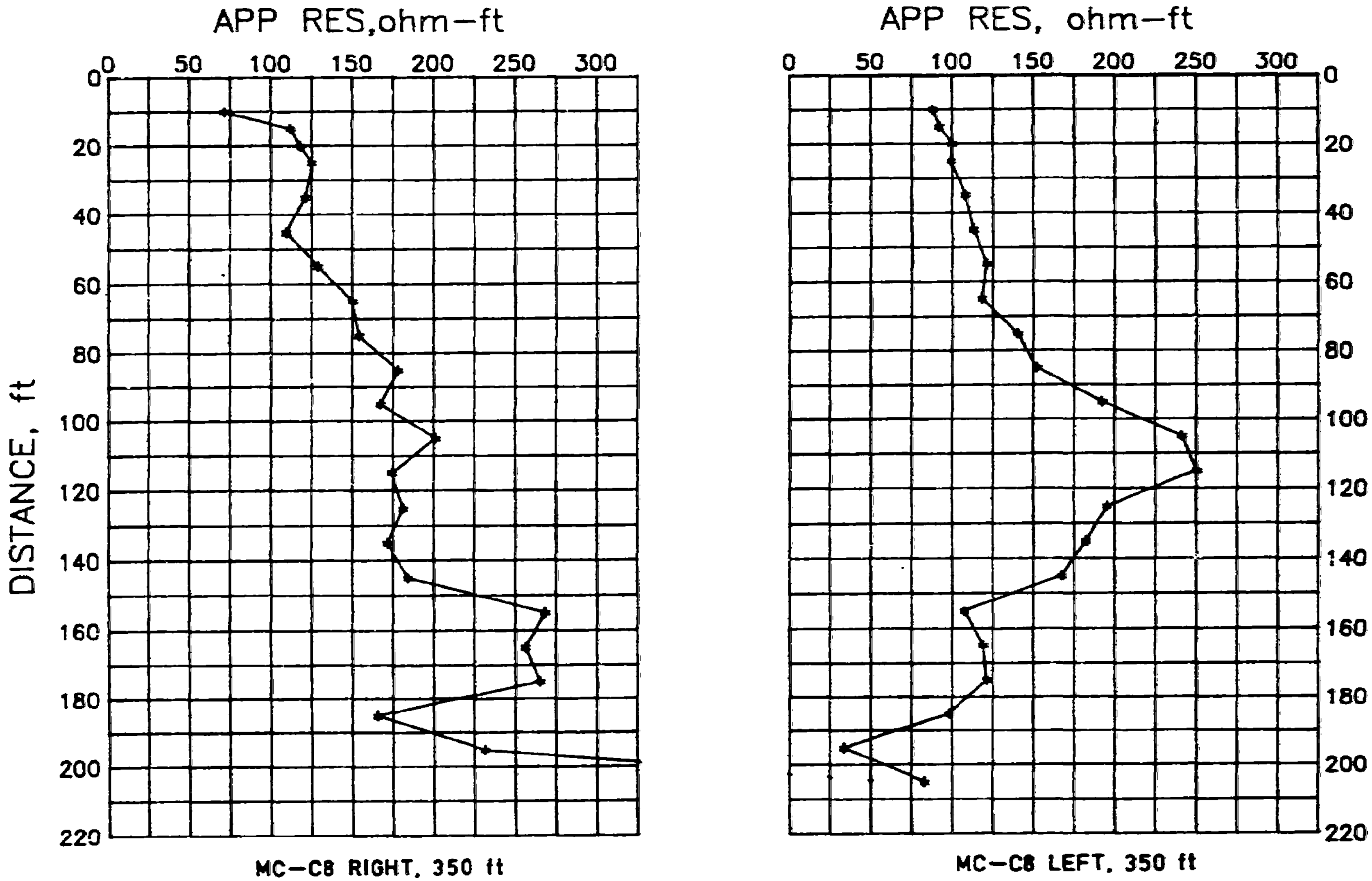


Figure C8. Pole-dipole survey. line C. 350 ft. right/left. 'raw' data plot.

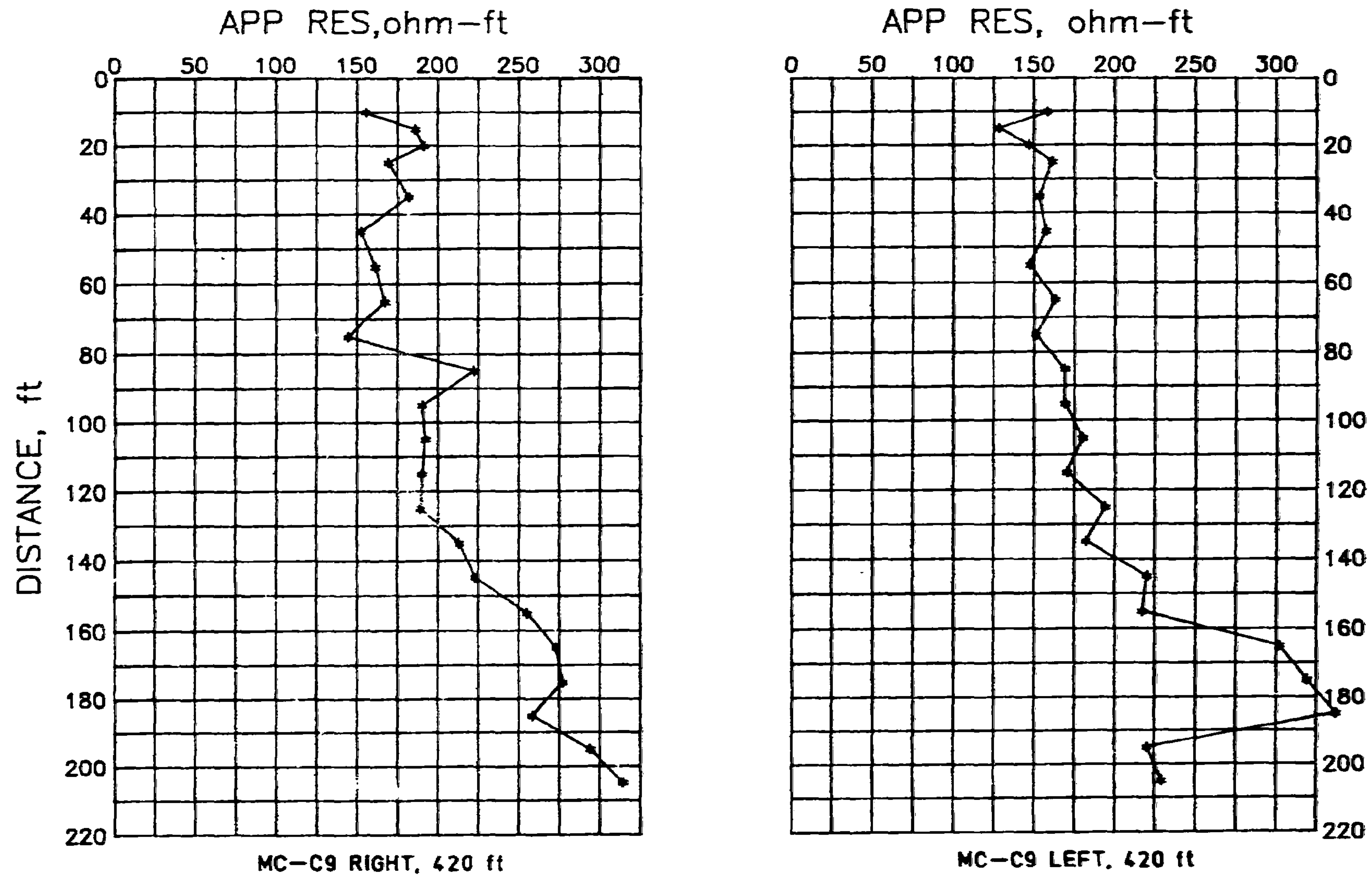


Figure C9. Pole-dipole survey, line C, 420 ft, right/left, 'raw' data plot.

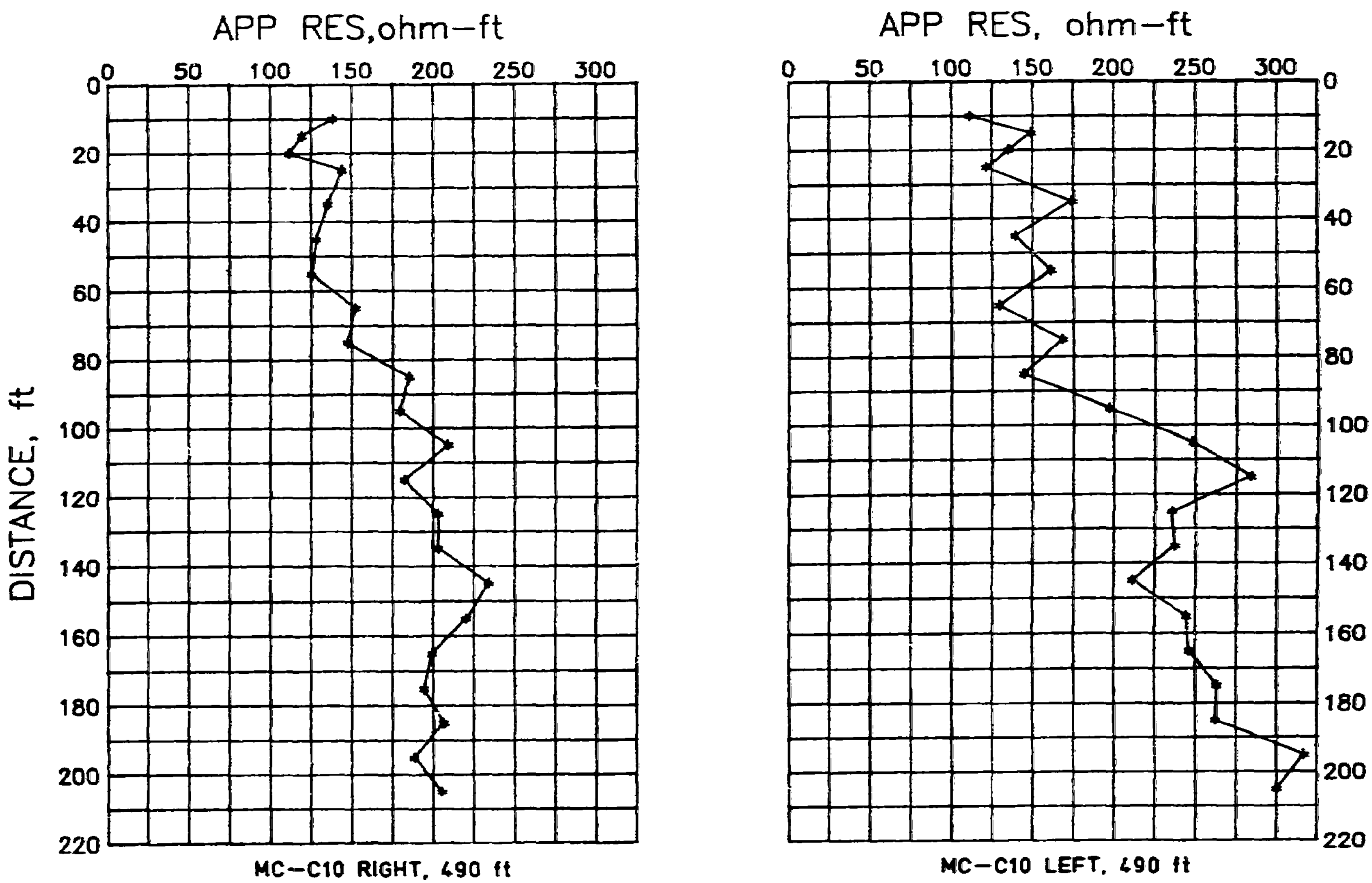


Figure C10. Pole-dipole survey, line C. 490 ft. right/left. 'raw' data plot.

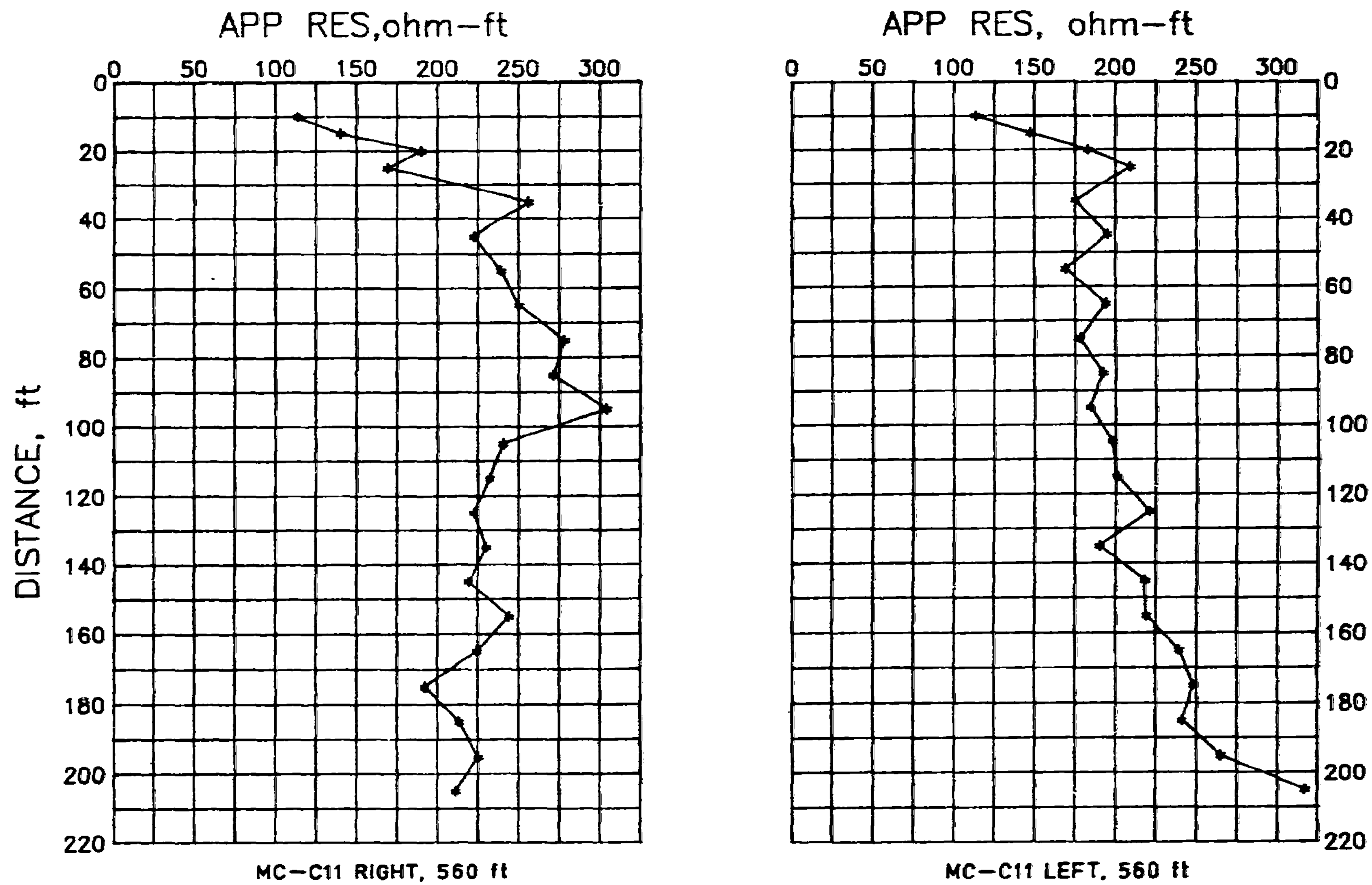


Figure C11. Pole-dipole survey, line C, 560 ft, right/left, 'raw' data plot.

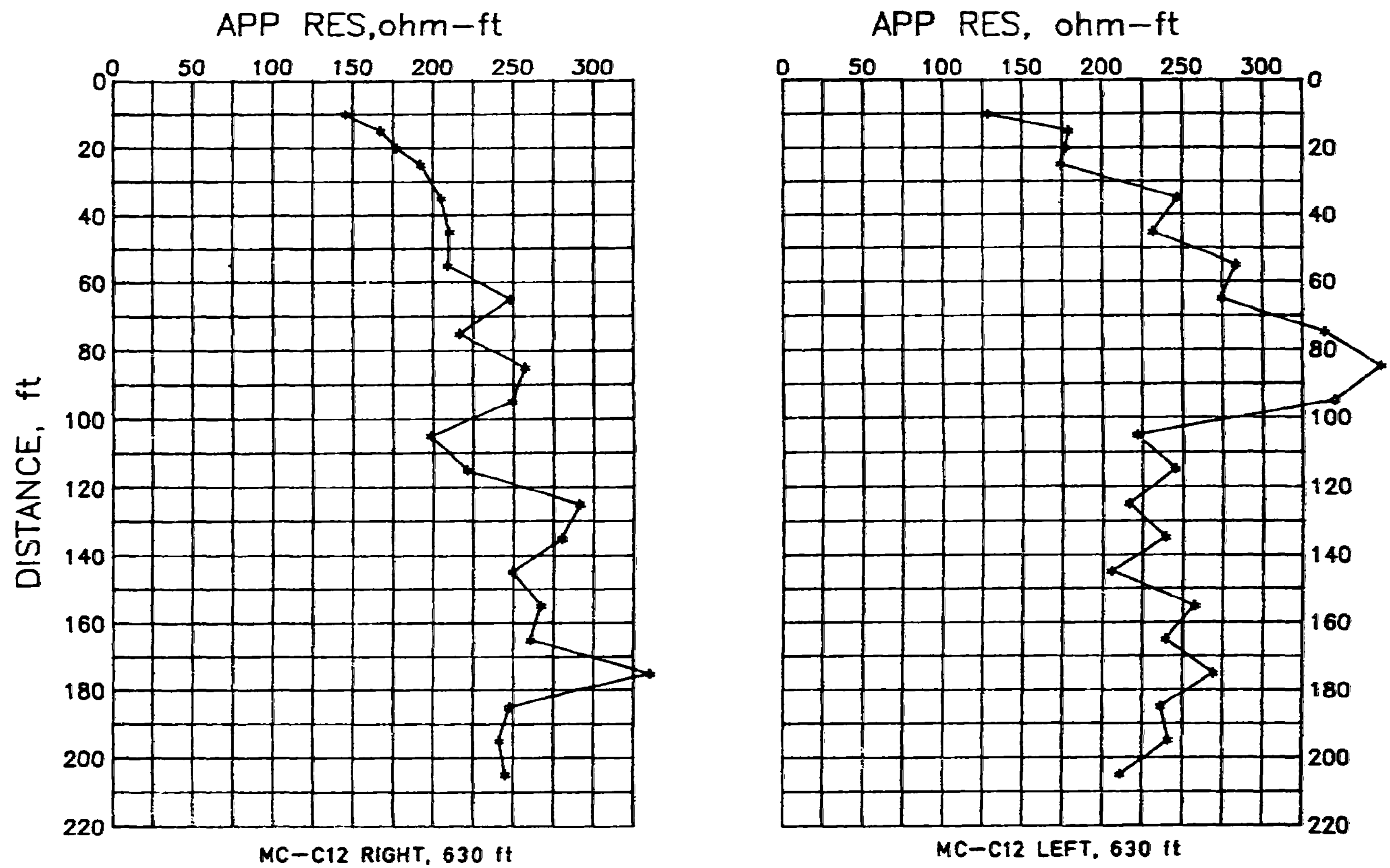


Figure C12. Pole-dipole survey, line C, 630 ft, right/left, 'raw' data plot.

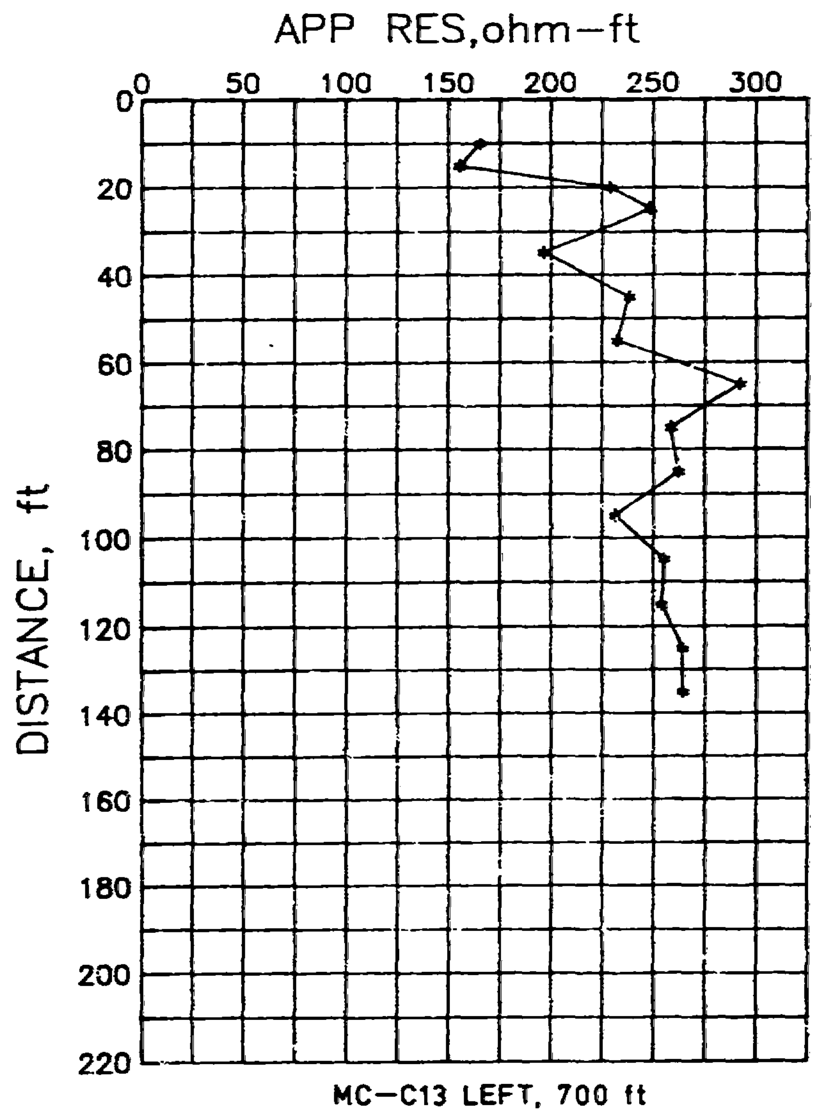


Figure C13. Pole-dipole survey. line C, 700 ft, left. 'raw' data plot.

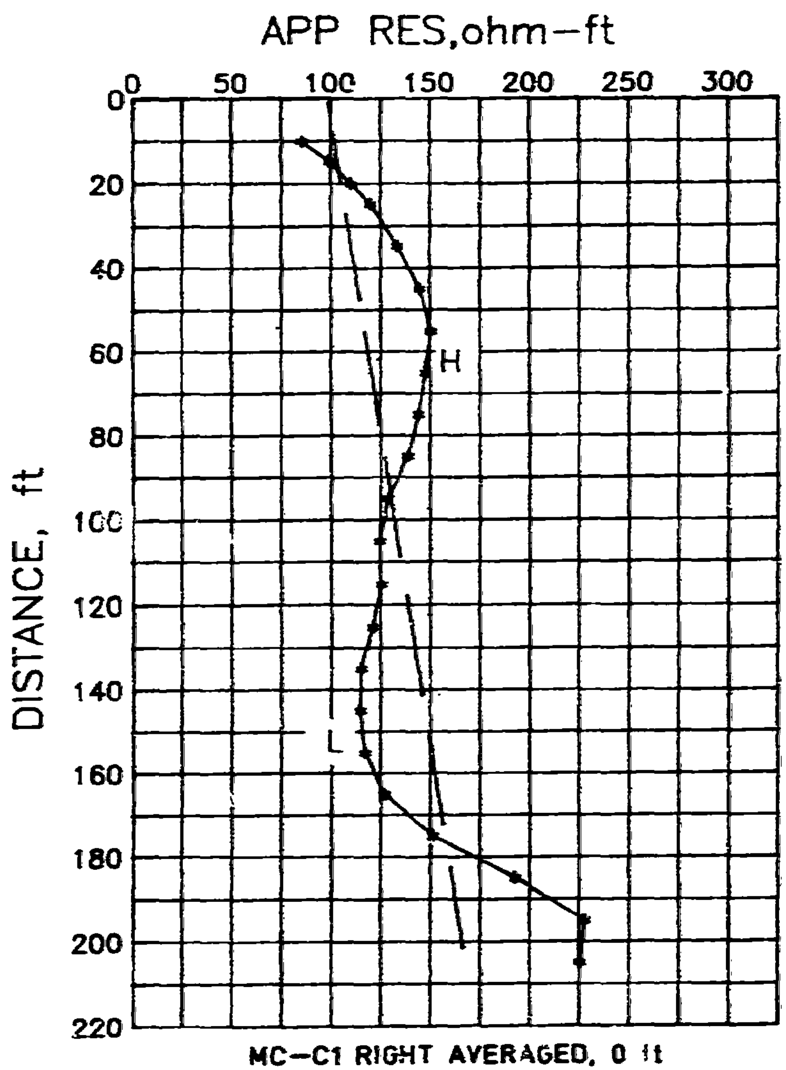


Figure C14. Pole-dipole survey. line C. 0 ft. right. smoothed data plot.

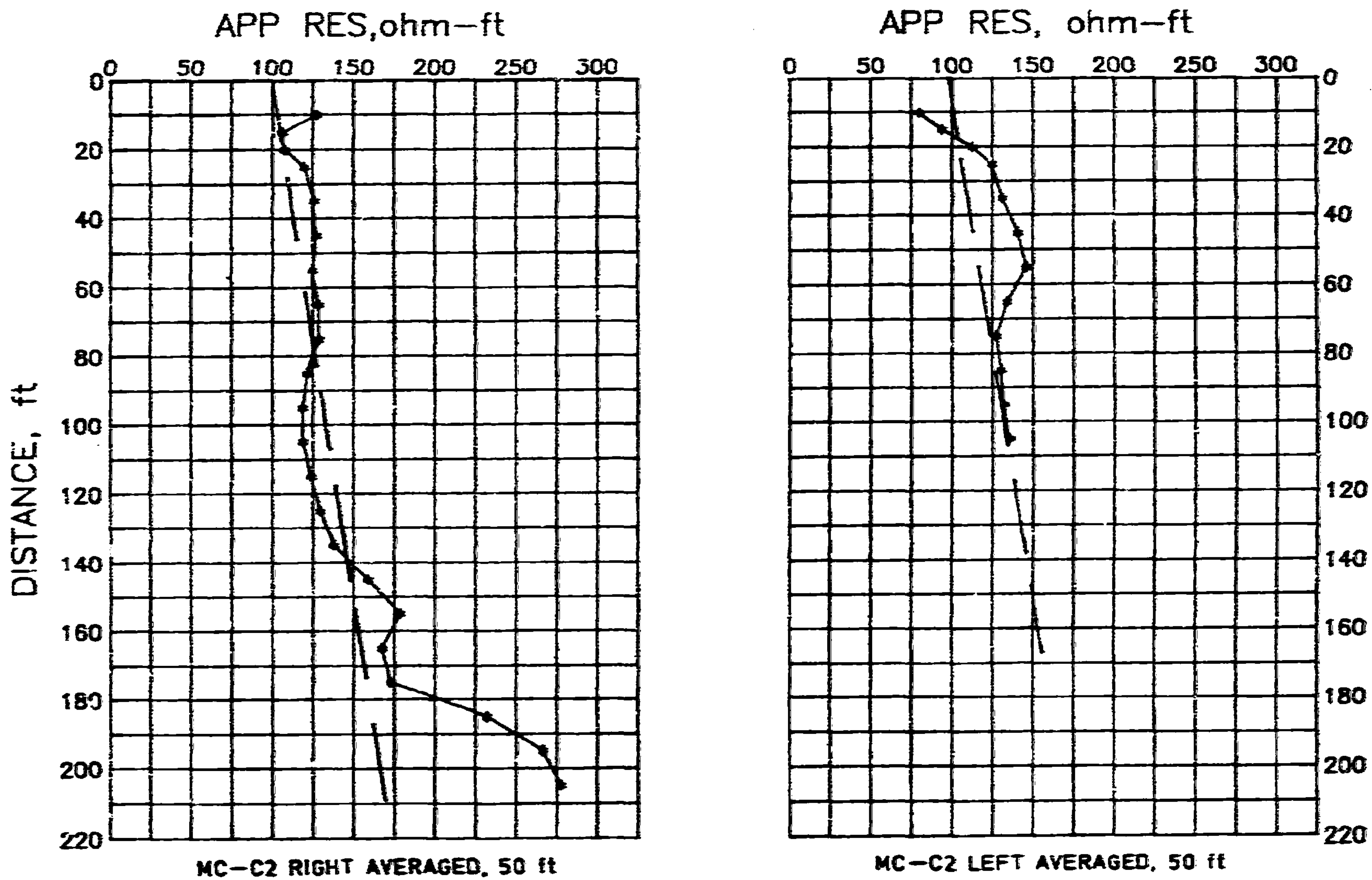


Figure C15. Pole-dipole survey, line C, 50 ft, right/left, smoothed data plot.

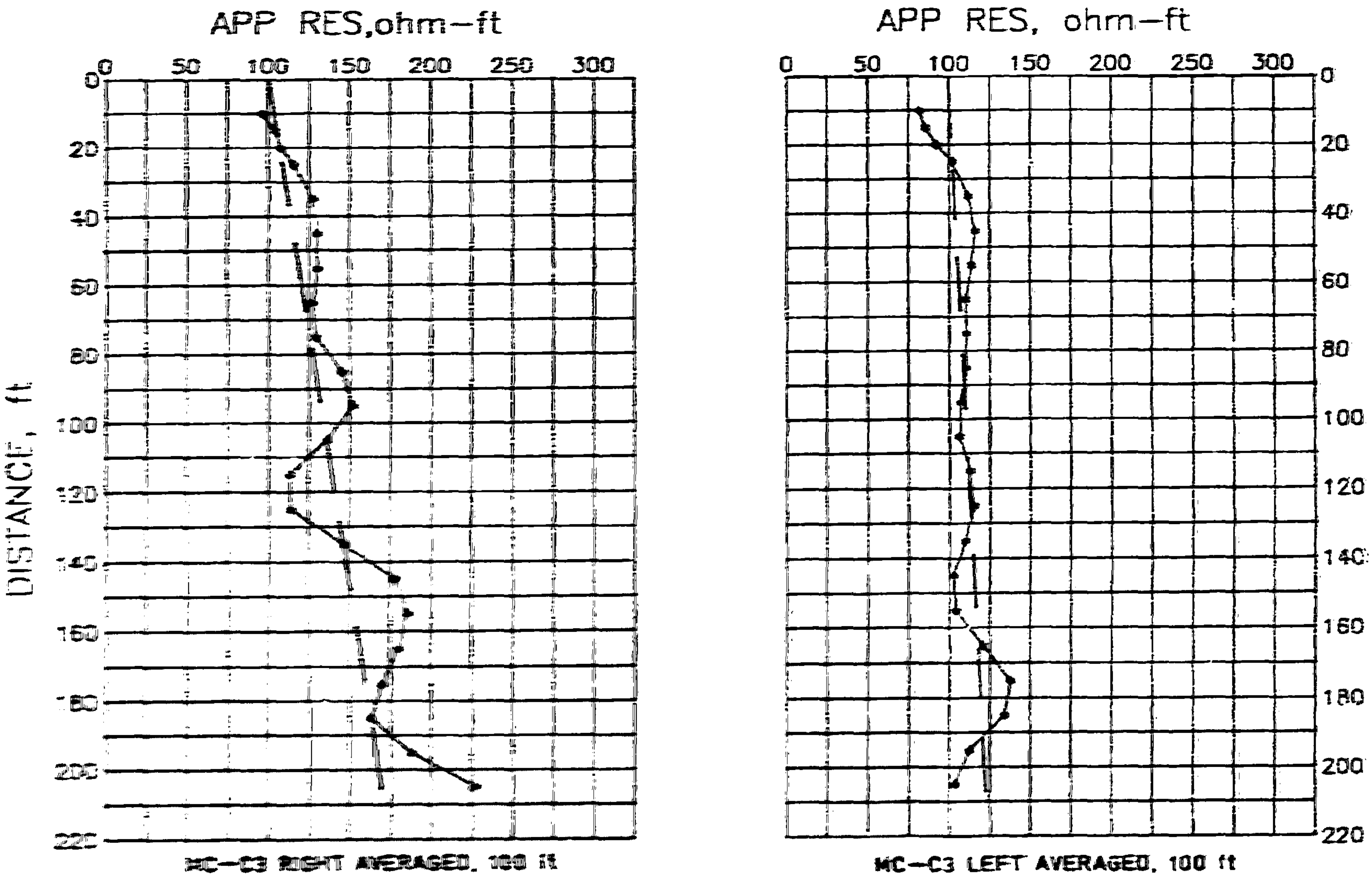
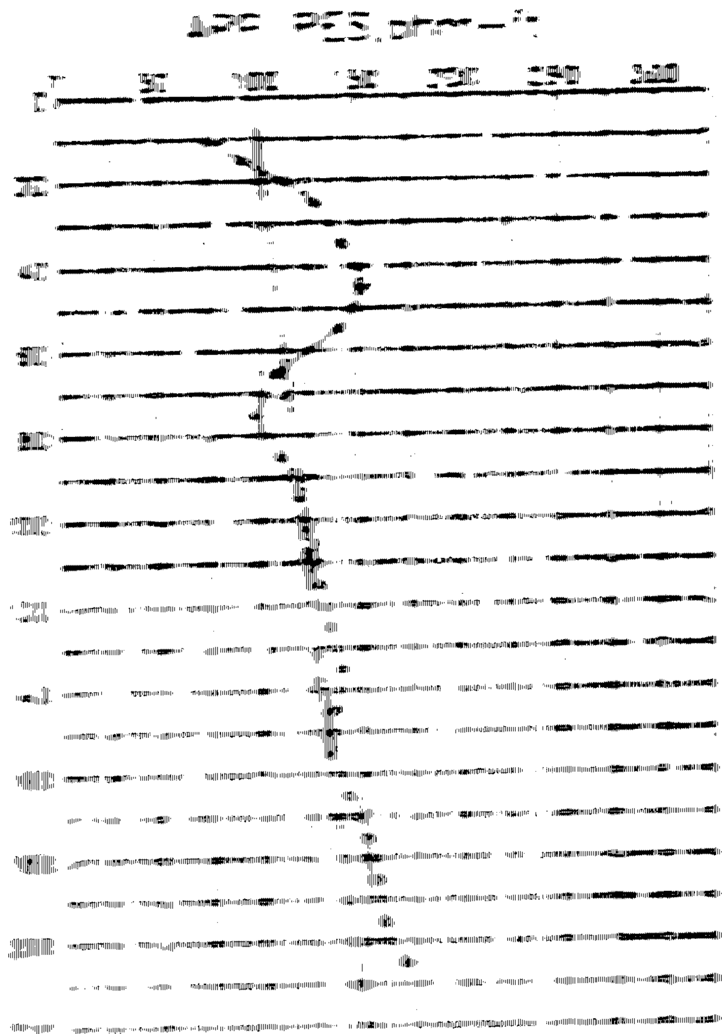
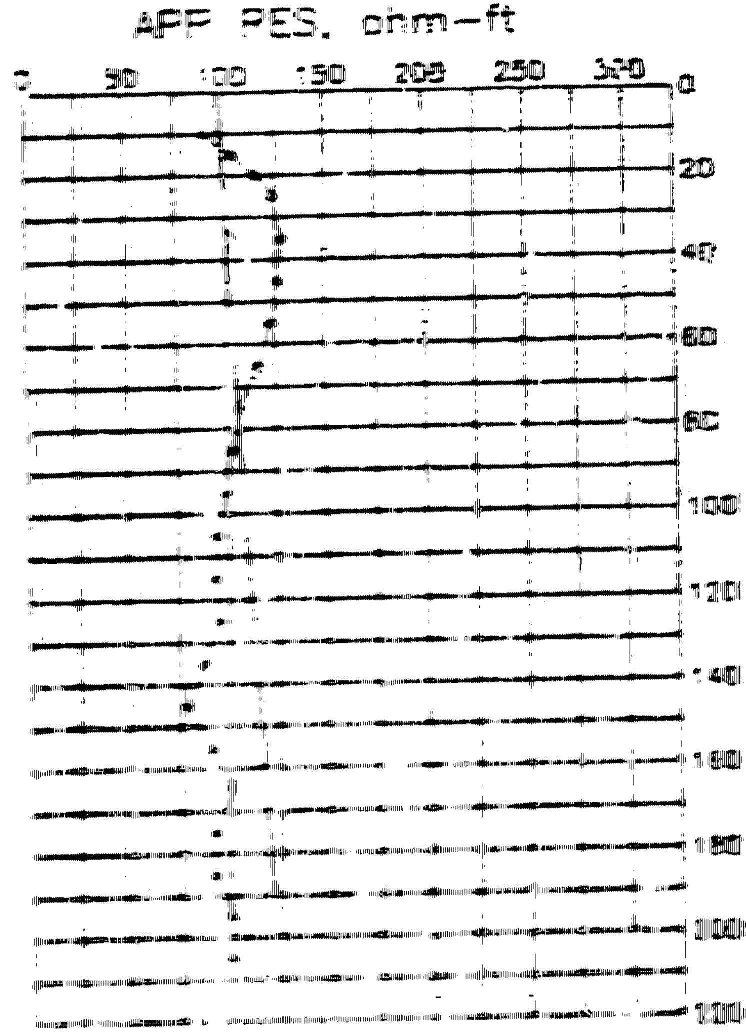


Figure C15. Pole-dipole survey, line C, 100 ft, right/left, smoothed data plot.




APP RES. ohm-ft
0
50
150
250
0
20
40
60
100
140

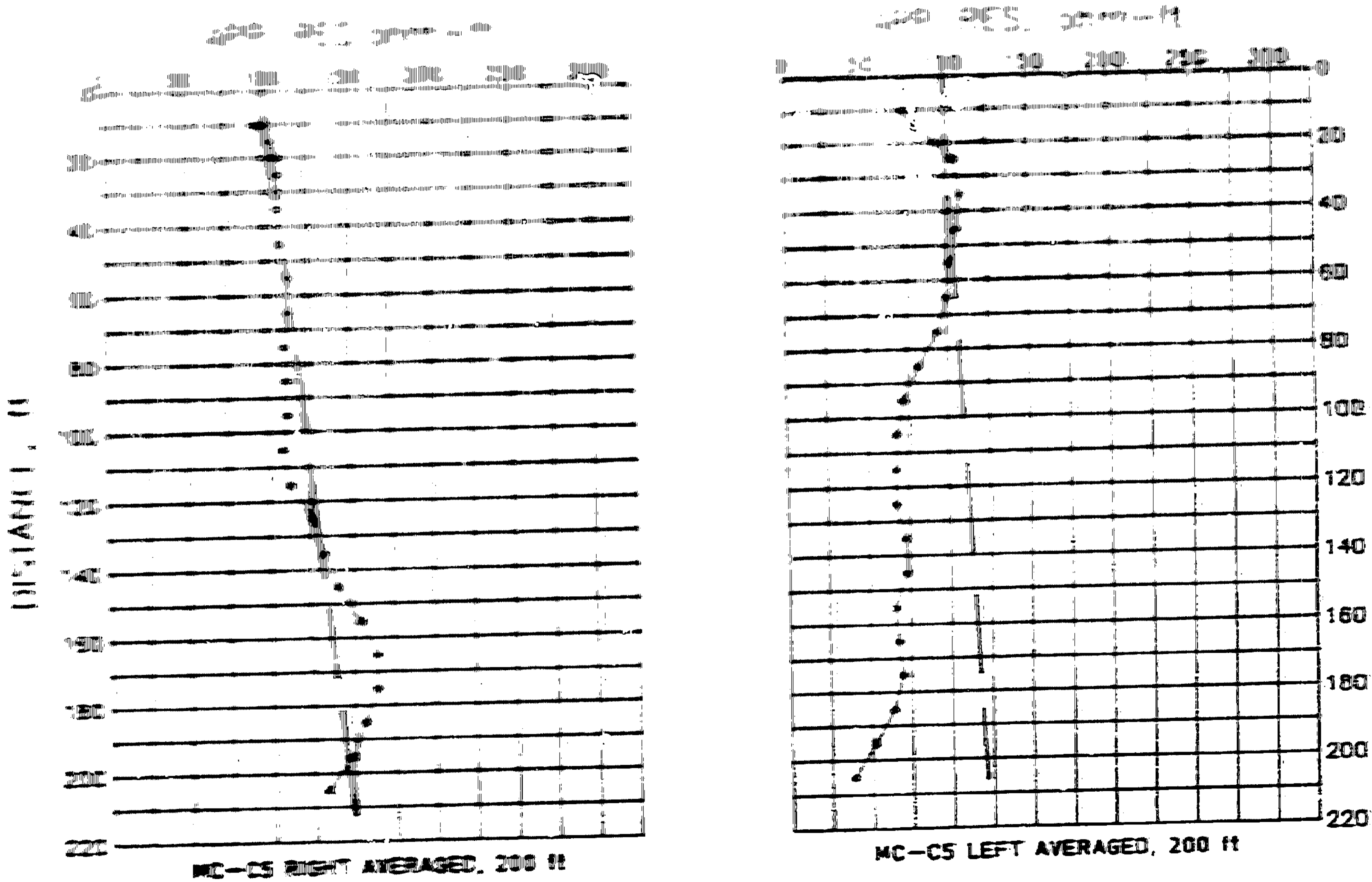


Figure C-1a. Pole-dipole survey, line C, 200 ft, right/left, smoothed data plot.

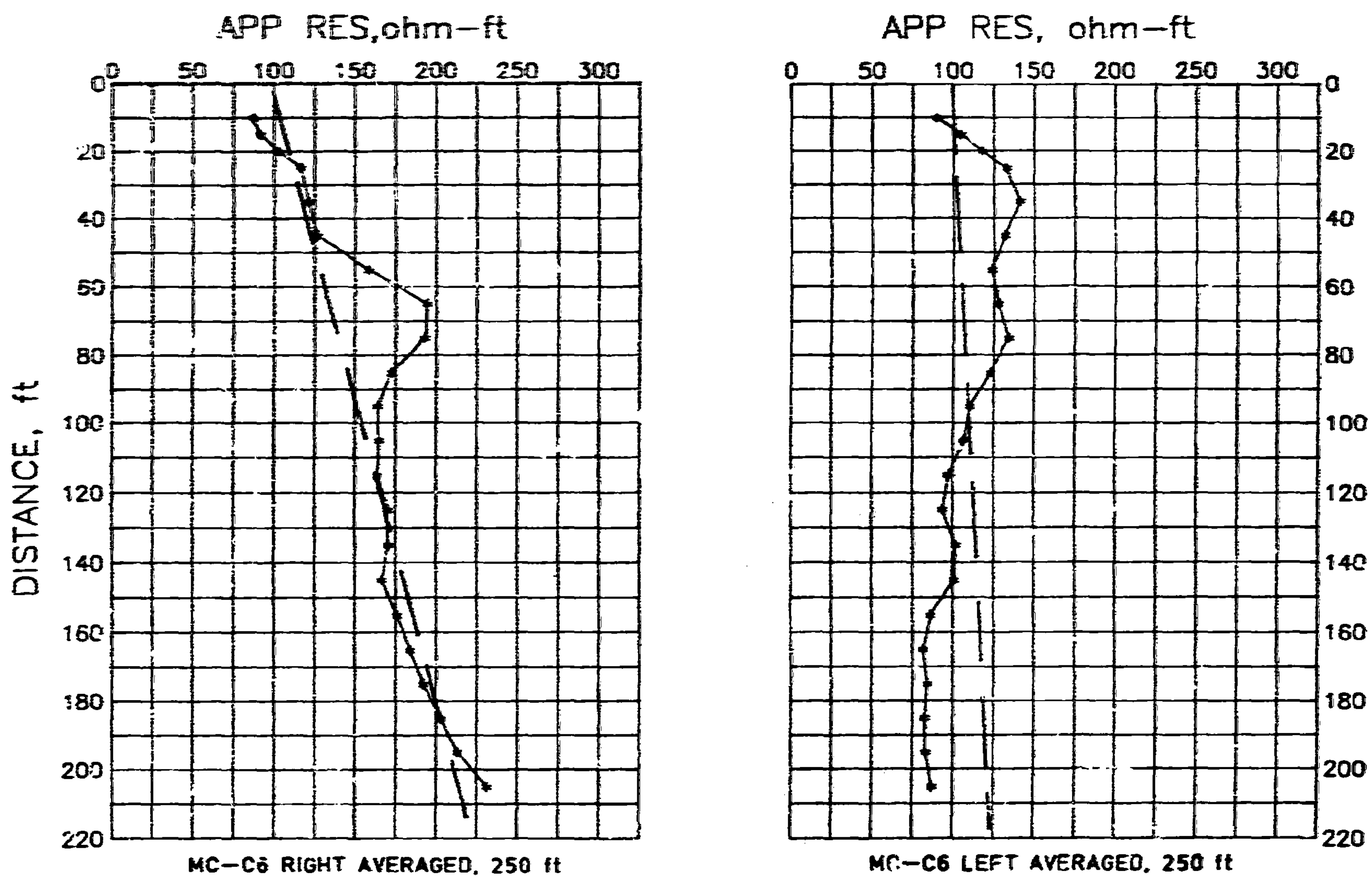


Figure C19. Pole-dipole survey, line C, 250 ft, right/left. smoothed data plot.

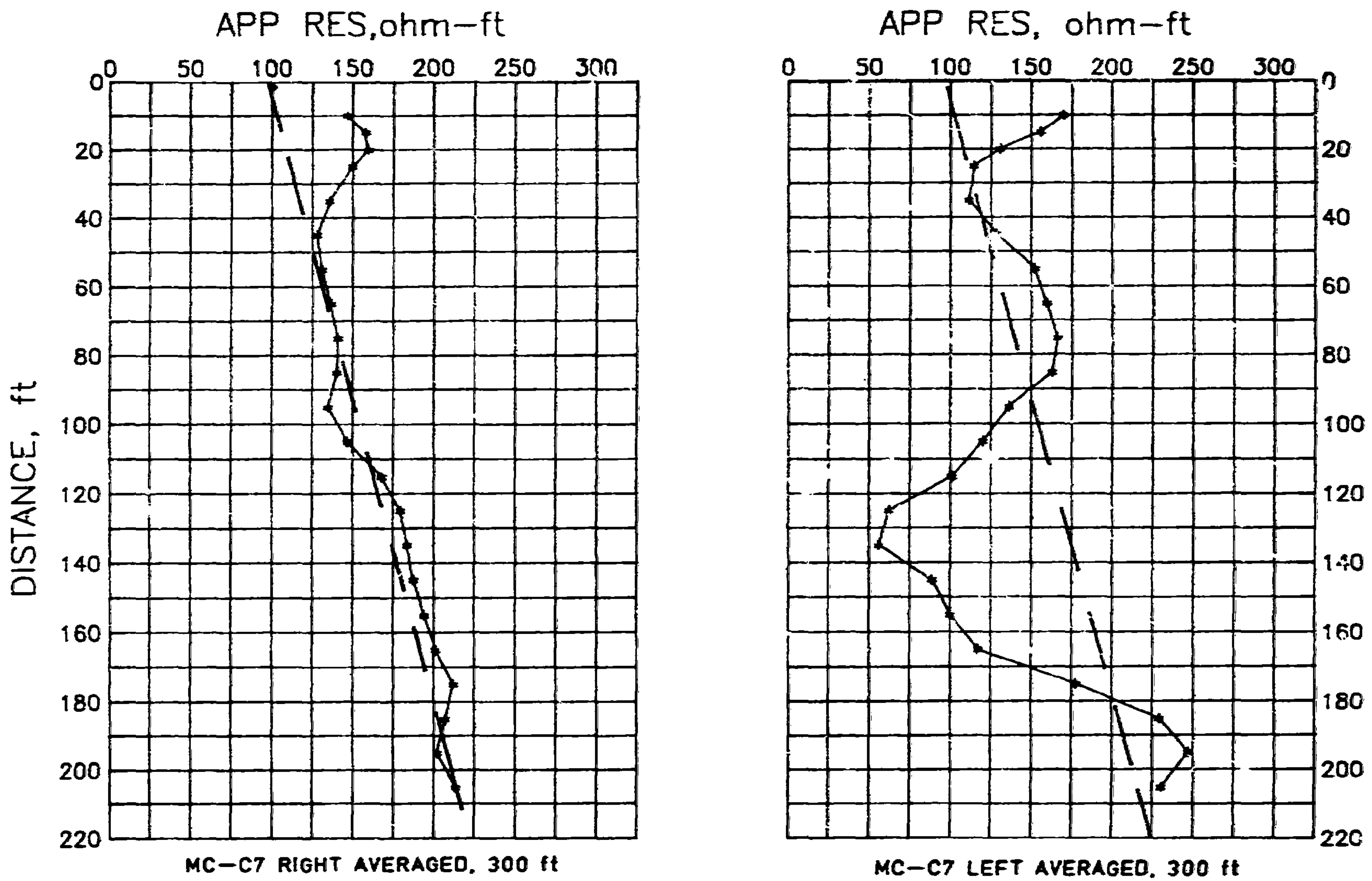


Figure C20. Pole-dipole survey, line C, 300 ft, right/left, smoothed data plot.

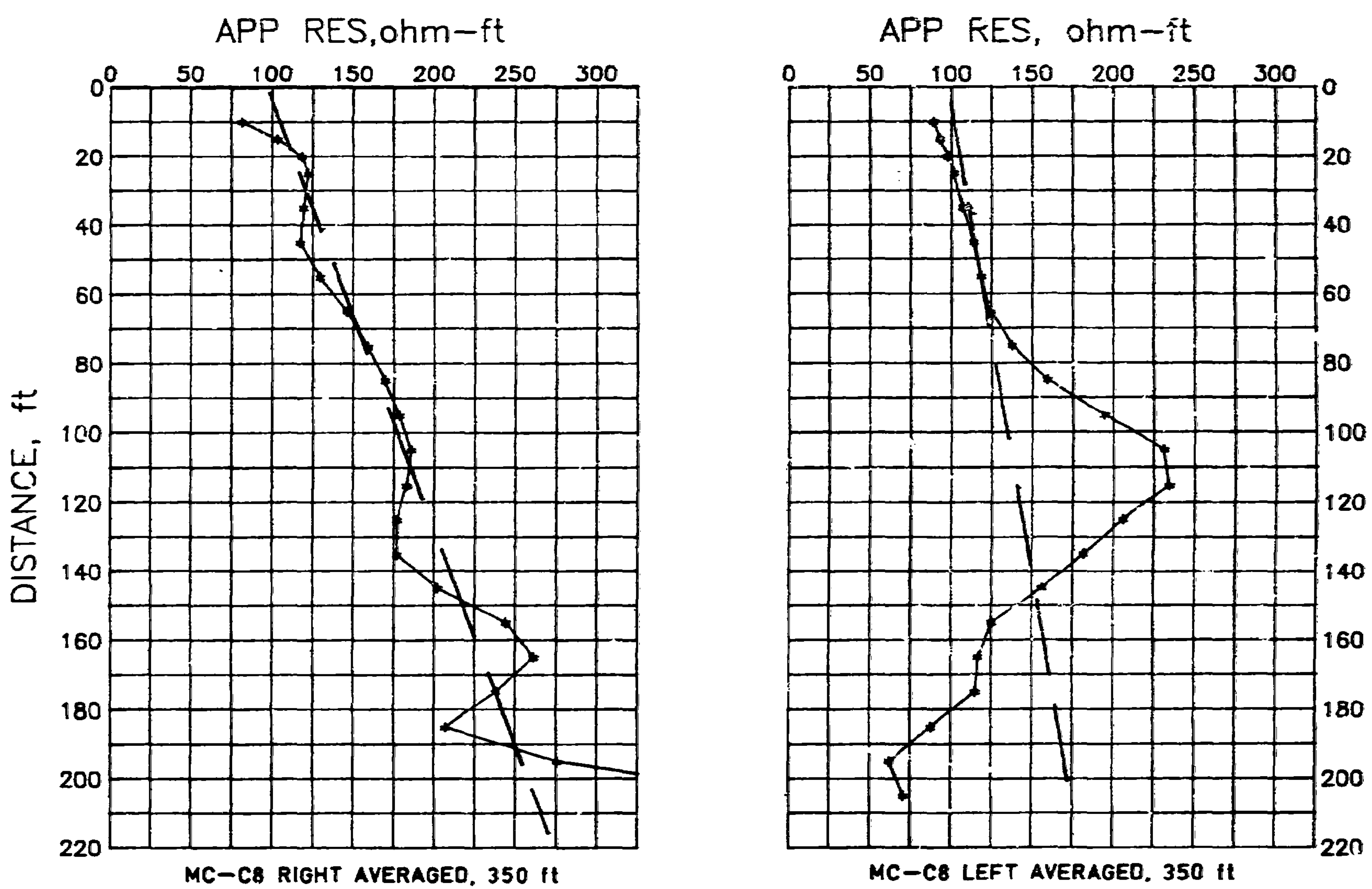


Figure C21. Pole-dipole survey. line C. 350 ft. right/left. smoothed data plot.

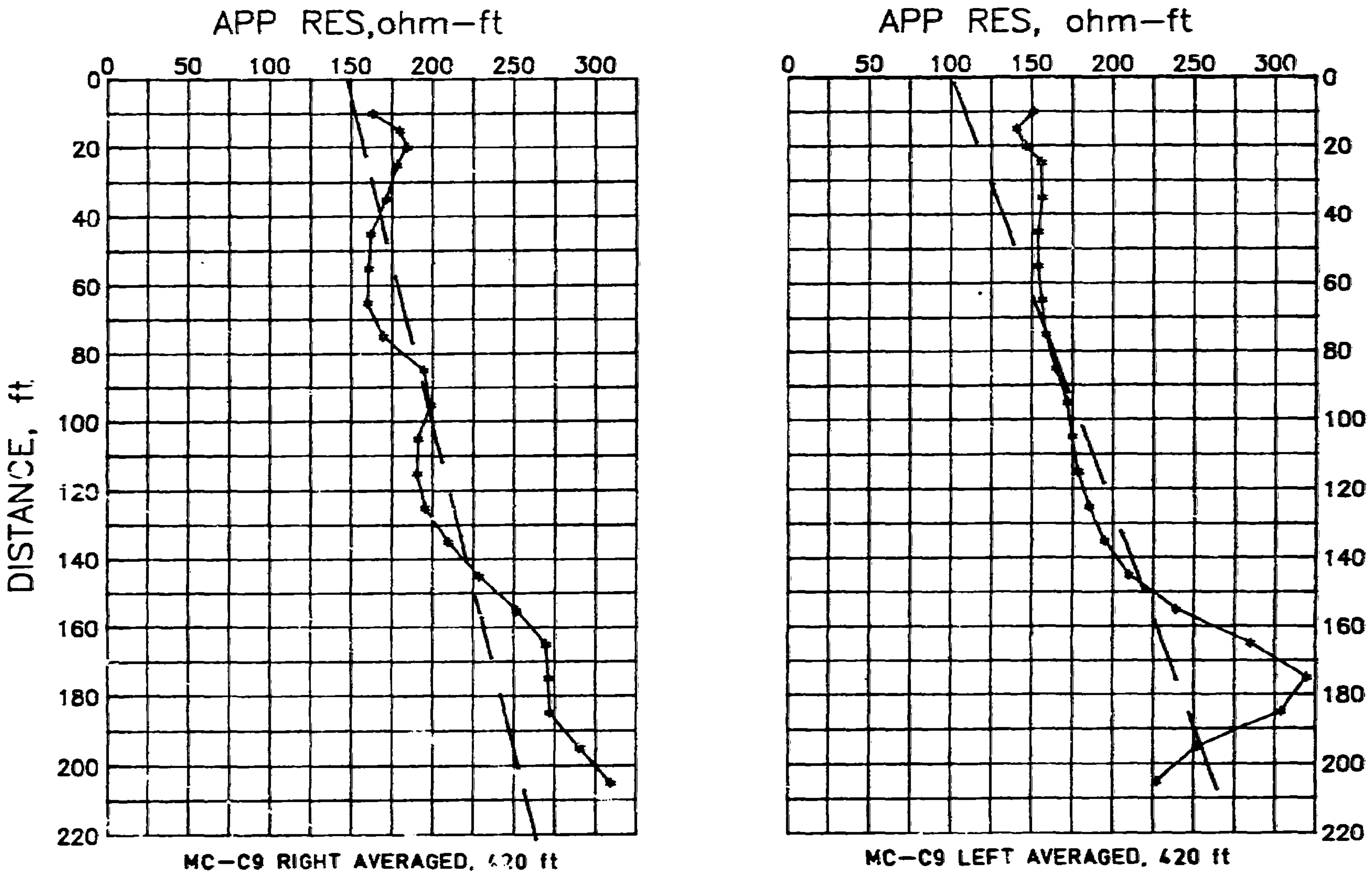


Figure C22. Pole-dipole survey, line C. 420 ft, right/left, smoothed data plot.

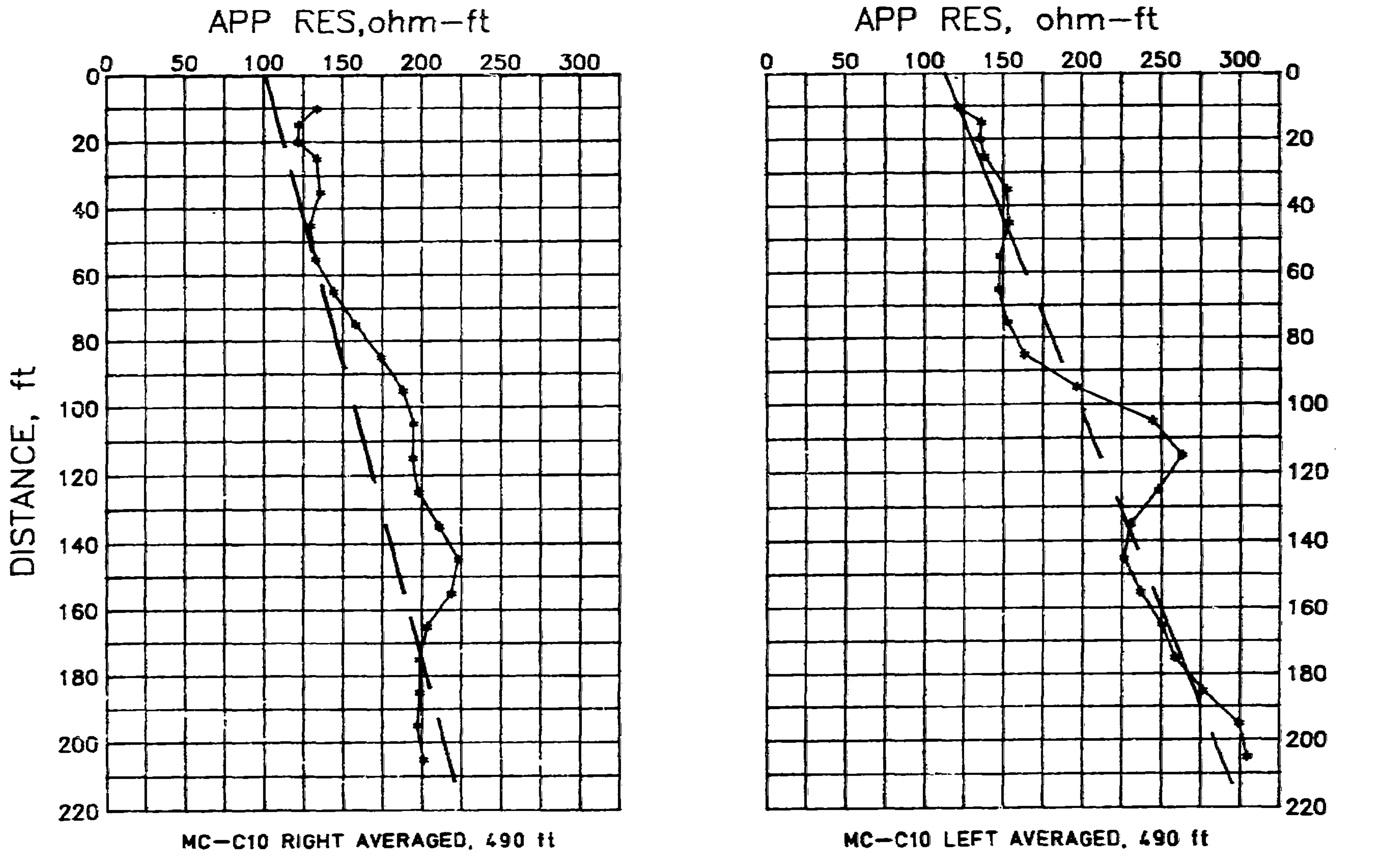


Figure C23. Pole-dipole survey, line C, 490 ft, right/left, smoothed data plot.

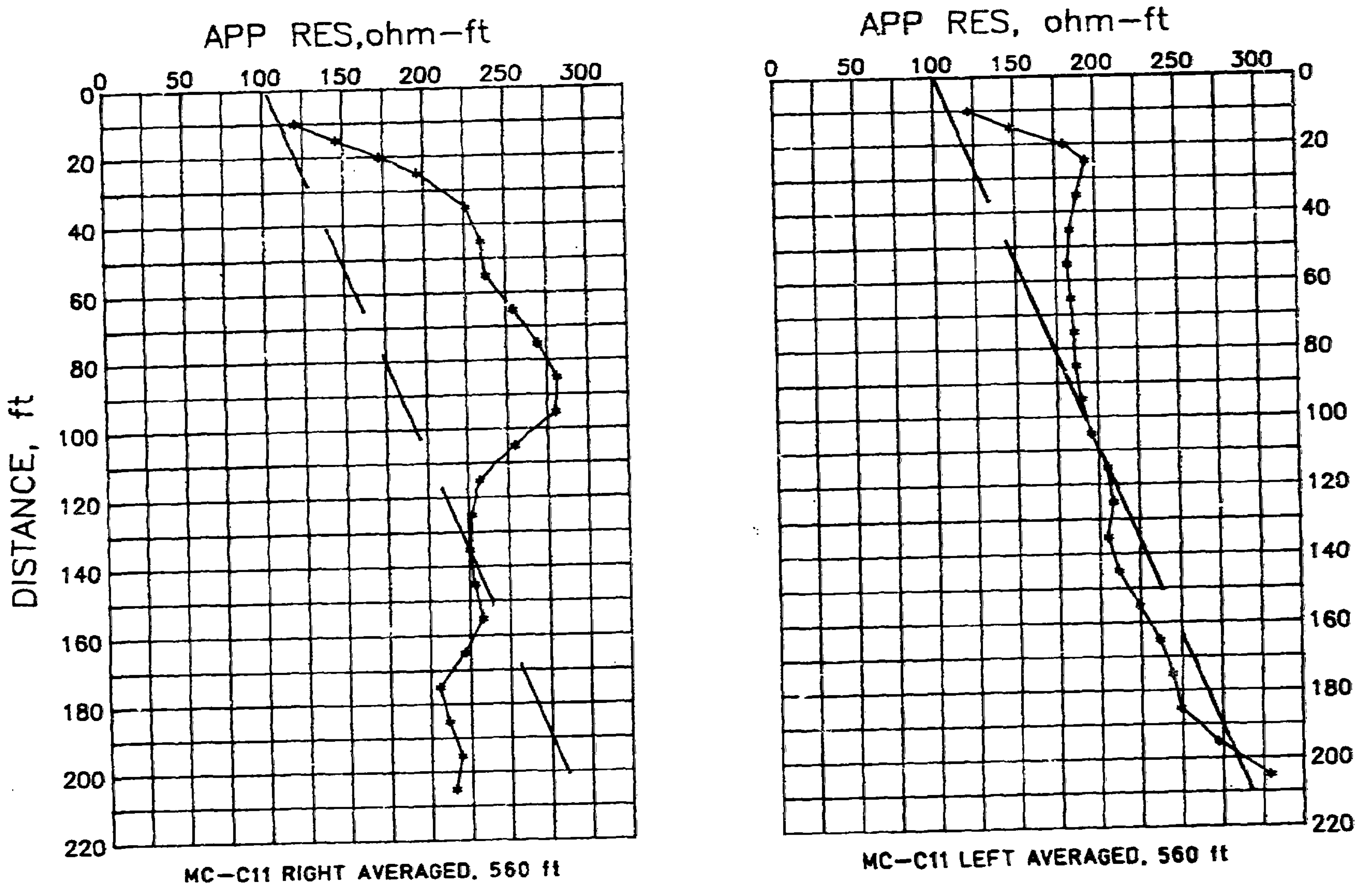


Figure C24. Pole-dipole survey. line C. 560 ft. right/left. smoothed data plot.

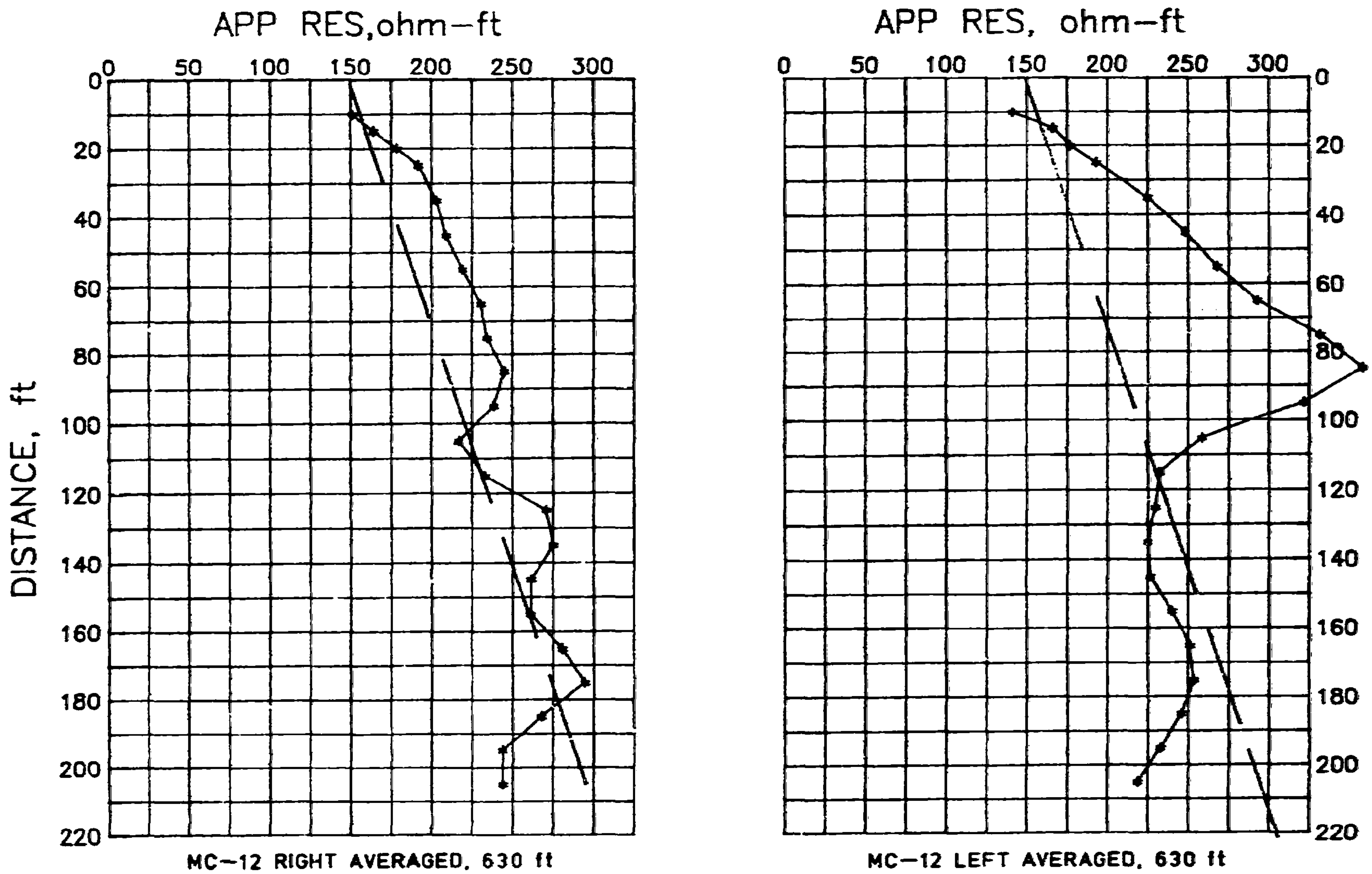


Figure C25. Pole-dipole survey, line C, 630 ft, right/left, smoothed data plot.

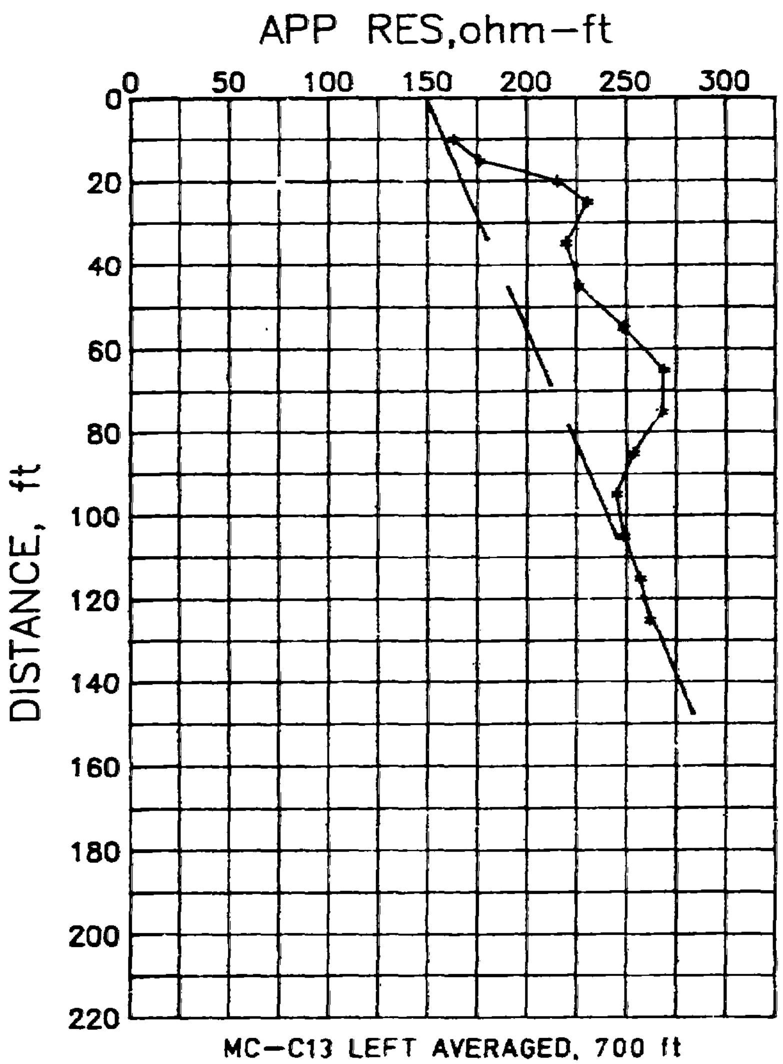


Figure C26. Pole-dipole survey, line C, 700 ft, left, smoothed data plot.

APPENDIX D

MEASURED AND CORRECTED GRAVITY DATA

******************<<< DATA SUMMARY >>>******************

PROGRAM: mcb1   FILE: \milcrk\mcb1.gpf

BASE STATION (X,Y)	7199 5131
REFERENCE ELEV.	1268.59
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	3407
LATITUDE	0460355
LONGITUDE	1181552
DATE	042489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7199.00	5131.00	1268.59	11.8	3407	3679.8
2	7180.00	5166.00	1268.72	11.8	3395	3669.7
3	7172.00	5185.00	1268.68	11.9	3433	3705.4
4	7148.00	5238.00	1268.60	11.9	3437	3692.4
5	7135.00	5278.00	1268.62	11.9	3434	3682.9
6	7128.00	5320.00	1268.84	12.0	3427	3682.8
7	7125.00	5362.00	1269.05	12.0	3407	3668.0
8	7121.00	5402.00	1269.05	12.1	3406	3658.5
9	7120.00	5423.00	1268.97	12.1	3409	3653.8
10	7135.00	5279.00	1268.62	12.2	3427	3686.1
11	7214.00	5114.00	1268.64	12.3	3394	3695.5
12	7199.00	5131.00	1268.59	12.3	3384	3679.8

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
3407.00	0.00	0.00	0.00	0.00	0.00	3679.83
3395.00	-2.19	0.00	-35.00	-8.64	9.24	3669.67
3433.00	-4.38	0.00	-54.00	-13.32	6.40	3705.38
3437.00	-5.85	0.00	-107.00	-26.40	0.71	3692.39
3434.00	-8.04	0.00	-147.00	-36.27	2.13	3682.90
3427.00	-10.23	0.00	-189.00	-46.63	17.76	3682.80
3407.00	-12.42	0.00	-231.00	-56.99	32.69	3667.95
3406.00	-13.88	0.00	-271.00	-66.86	32.69	3658.46
3409.00	-16.80	0.00	-292.00	-72.04	27.00	3653.76
3427.00	-19.00	0.00	-148.00	-36.51	2.13	3686.05
3394.00	-21.92	0.00	17.00	4.19	3.56	3695.46
3384.00	-24.84	0.00	0.00	0.00	0.00	3679.83

******************<<< DATA SUMMARY >>>******************

PROGRAM: mcb2   FILE: \milcrk\mcb2.gpf

BASE STATION (X,Y)	7199 5131
REFERENCE ELEV.	1268.59
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	3407
LATITUDE	0460355
LONGITUDE	1181552
DATE	042489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7199.00	5131.00	1268.59	12.3	3384	3679.8
2	7228.00	5099.00	1268.61	12.4	3379	3686.2
3	7254.00	5069.00	1268.56	12.4	3370	3681.5
4	7286.00	5040.00	1268.72	12.5	3342	3671.6
5	7318.00	5016.00	1268.75	12.5	3323	3660.9
6	7352.00	4987.00	1268.65	12.6	3308	3646.6
7	7385.00	4965.00	1268.47	12.6	3293	3624.8
8	7414.00	4942.00	1268.42	12.7	3278	3612.6
9	7433.00	4931.00	1268.51	12.7	3259	3603.0
10	7318.00	5016.00	1268.75	12.8	3300	3645.8
11	7180.00	5166.00	1268.72	12.8	3373	3687.3
12	7199.00	5131.00	1268.59	12.9	3365	3679.8

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
3384.00	0.00	0.00	0.00	0.00	0.00	3679.83
3379.00	-2.41	0.00	32.00	7.90	1.42	3686.16
3370.00	-3.62	0.00	62.00	15.30	-2.12	3681.50
3342.00	-5.43	0.00	91.00	22.45	9.24	3671.59
3323.00	-7.24	0.00	115.00	28.37	11.37	3660.93
3308.00	-9.05	0.00	144.00	35.53	4.27	3646.60
3293.00	-10.86	0.00	166.00	40.96	-8.53	3624.84
3278.00	-12.68	0.00	189.00	46.63	-12.07	3612.58
3259.00	-14.49	0.00	200.00	49.34	-5.68	3602.97
3300.00	-16.90	0.00	115.00	28.37	11.37	3645.75
3373.00	-18.71	0.00	-35.00	-8.64	9.24	3687.26
3365.00	-20.52	0.00	0.00	0.00	0.00	3679.83

Figure D1. Gravity Data, Line B

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcb3   FILE: \milcrk\mcb3.gpf

BASE STATION (X,Y)	7199 5131
REFERENCE ELEV.	1268.59
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	3407
LATITUDE	0460355
LONGITUDE	1181552
DATE	042489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7199.00	5131.00	1268.59	12.9	3365	3679.8
2	7192.00	5149.00	1268.66	13.0	3367	3690.4
3	7172.00	5185.00	1268.68	13.0	3378	3698.8
4	7155.00	5222.00	1268.55	13.1	3376	3682.2
5	7141.00	5260.00	1268.53	13.1	3385	3683.8
6	7131.00	5300.00	1268.72	13.2	3369	3674.1
7	7126.00	5340.00	1268.99	13.2	3353	3668.7
8	7123.00	5381.00	1269.15	13.2	3346	3665.1
9	7120.00	5423.00	1268.97	13.3	3355	3654.3
10	7135.00	5279.00	1268.62	13.3	3368	3684.2
11	7199.00	5131.00	1268.59	13.4	3326	3679.8

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
3365.00	0.00	0.00	0.00	0.00	0.00	3679.83
3367.00	-7.90	0.00	-18.00	-4.44	4.98	3690.43
3378.00	-11.85	0.00	-54.00	-13.32	6.40	3698.80
3376.00	-15.80	0.00	-91.00	-22.45	-2.84	3682.22
3385.00	-18.43	0.00	-129.00	-31.83	-4.26	3683.78
3369.00	-22.38	0.00	-169.00	-41.70	9.24	3674.07
3353.00	-25.01	0.00	-209.00	-51.56	28.42	3668.74
3346.00	-27.64	0.00	-250.00	-61.68	39.79	3665.07
3355.00	-30.28	0.00	-292.00	-72.04	27.00	3654.27
3368.00	-35.54	0.00	-148.00	-36.51	2.13	3684.23
3326.00	-42.12	0.00	0.00	0.00	0.00	3679.83

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcb4   FILE: \milcrk\mcb4.gpf

BASE STATION (X,Y)	7199 5131
REFERENCE ELEV.	1268.59
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	3407
LATITUDE	0460355
LONGITUDE	1181552
DATE	042489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7199.00	5131.00	1268.59	13.4	3326	3679.8
2	7214.00	5114.00	1268.64	13.5	3322	3684.5
3	7240.00	5083.00	1268.55	13.5	3320	3684.8
4	7270.00	5054.00	1268.68	13.6	3294	3674.4
5	7300.00	5028.00	1268.74	13.6	3279	3669.7
6	7286.00	5040.00	1268.72	13.7	3280	3668.0
7	7334.00	5001.00	1268.70	13.7	3257	3652.6
8	7367.00	4976.00	1268.58	13.8	3251	3644.6
9	7401.00	4954.00	1268.51	13.8	3238	3632.3
10	7433.00	4931.00	1268.51	13.9	3200	3598.1
11	7300.00	5028.00	1268.74	13.9	3268	3665.6
12	7199.00	5131.00	1268.59	14.0	3313	3679.8

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
3326.00	0.00	0.00	0.00	0.00	0.00	3679.83
3322.00	-1.24	0.00	17.00	4.19	3.56	3684.50
3320.00	-2.48	0.00	48.00	11.84	-2.84	3684.84
3294.00	-3.72	0.00	77.00	19.00	6.40	3674.39
3279.00	-4.54	0.00	103.00	25.41	10.66	3669.68
3280.00	-6.19	0.00	91.00	22.45	9.24	3668.03
3257.00	-7.43	0.00	130.00	32.07	7.81	3652.63
3251.00	-8.26	0.00	155.00	38.24	-0.71	3644.62
3238.00	-9.50	0.00	177.00	43.67	-5.68	3632.27
3200.00	-10.74	0.00	200.00	49.34	-5.68	3598.14
3268.00	-12.39	0.00	103.00	25.41	10.66	3665.65
3313.00	-14.04	0.00	0.00	0.00	0.00	3679.83

Figure D2. Gravity Data, Line B

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcc1 FILE: \milcrk\mcc1.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	11.1	5076	5482.5
2	7316.00	5243.00	1244.01	11.2	4942	5457.2
3	7298.00	5278.00	1246.55	11.3	4769	5444.3
4	7281.00	5314.00	1248.52	11.4	4634	5432.5
5	7265.00	5351.00	1250.54	11.5	4497	5420.7
6	7337.00	5210.00	1242.25	11.6	5065	5482.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5076.00	0.00	0.00	0.00	0.00	0.00	5482.49
4942.00	-2.52	0.00	-33.00	-8.14	125.05	5457.19
4769.00	-4.68	0.00	-68.00	-16.77	305.53	5444.34
4634.00	-7.56	0.00	-104.00	-25.65	445.50	5432.51
4497.00	-9.36	0.00	-141.00	-34.77	589.03	5420.74
5065.00	-11.88	0.00	0.00	0.00	0.00	5482.49

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcc2 FILE: \milcrk\mcc2.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	11.7	5055	5482.5
2	7326.00	5226.00	1243.08	11.8	5015	5498.4
3	7307.00	5260.00	1245.34	11.9	4828	5455.1
4	7298.00	5278.00	1246.55	12.0	4755	5461.8
5	7290.00	5296.00	1247.56	12.1	4687	5458.1
6	7273.00	5333.00	1249.53	12.2	4560	5455.8
7	7316.00	5243.00	1244.01	12.3	4929	5489.2
8	7337.00	5210.00	1242.25	12.3	5028	5482.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5055.00	0.00	0.00	0.00	0.00	0.00	5482.49
5015.00	-4.05	0.00	-16.00	-3.95	58.97	5498.36
4828.00	-10.53	0.00	-50.00	-12.33	219.55	5455.06
4755.00	-14.58	0.00	-68.00	-16.77	305.53	5461.80
4687.00	-17.01	0.00	-86.00	-21.21	377.29	5458.11
4560.00	-21.06	0.00	-123.00	-30.33	517.26	5455.84
4929.00	-25.92	0.00	-33.00	-8.14	125.05	5489.23
5028.00	-29.16	0.00	0.00	0.00	0.00	5482.49

Figure D3. Gravity Data, Line C

******************<<< DATA SUMMARY >>>******************

PROGRAM: mcc3 FILE: \milcrk\mcc3.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	12.4	5030	5482.5
2	7257.00	5369.00	1251.55	12.5	4401	5403.5
3	7242.00	5406.00	1253.67	12.6	4253	5373.0
4	7226.00	5443.00	1255.66	12.6	4123	5352.8
5	7211.00	5480.00	1257.33	12.8	4021	5334.0
6	7273.00	5333.00	1249.53	12.8	4545	5366.8
7	7290.00	5296.00	1247.56	12.9	4693	5380.7
8	7337.00	5210.00	1242.25	13.1	5145	5482.5

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5030.00	0.00	0.00	0.00	0.00	0.00	5482.49
4401.00	21.21	0.00	-159.00	-39.21	660.79	5403.49
4253.00	33.32	0.00	-196.00	-48.33	811.42	5373.03
4123.00	45.44	0.00	-233.00	-57.46	952.82	5352.77
4021.00	63.62	0.00	-270.00	-66.58	1071.47	5333.95
4545.00	78.77	0.00	-123.00	-30.33	517.26	5366.81
4693.00	93.91	0.00	-86.00	-21.21	377.29	5380.67
5145.00	124.21	0.00	0.00	0.00	0.00	5482.49

******************<<< DATA SUMMARY >>>******************

PROGRAM: mcc4 FILE: \milcrk\mcc4.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	14.4	5202	5482.5
2	7249.00	5388.00	1252.62	14.4	4487	5402.0
3	7234.00	5424.00	1254.81	14.5	4349	5397.4
4	7218.00	5461.00	1256.57	14.6	4231	5384.3
5	7203.00	5498.00	1257.91	14.6	4160	5392.2
6	7242.00	5406.00	1253.67	14.7	4433	5406.9
7	7281.00	5314.00	1248.52	14.8	4768	5423.6
8	7337.00	5210.00	1242.25	14.9	5213	5482.5

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5202.00	0.00	0.00	0.00	0.00	0.00	5482.49
4487.00	1.15	0.00	-178.00	-43.89	736.81	5402.00
4349.00	3.45	0.00	-214.00	-52.77	892.42	5397.38
4231.00	4.98	0.00	-251.00	-61.90	1017.47	5384.32
4160.00	6.52	0.00	-288.00	-71.02	1112.68	5392.19
4433.00	8.05	0.00	-196.00	-48.33	811.42	5406.95
4768.00	9.96	0.00	-104.00	-25.65	445.50	5423.62
5213.00	11.88	0.00	0.00	0.00	0.00	5482.49

Figure D4. Gravity Data, Line C

**********************<<< DATA SUMMARY >>>**********************

PROGRAM: mcc5 FILE: \milcrk\mcc5.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	14.9	5212	5482.5
2	7234.00	5424.00	1254.81	15.0	4357	5395.5
3	7159.00	5536.00	1259.34	15.1	4081	5388.0
4	7153.00	5554.00	1268.07	15.2	4000	5345.3
5	7196.00	5517.00	1258.69	15.3	4103	5364.5
6	7326.00	5225.00	1243.08	15.4	5171	5477.0
7	7337.00	5210.00	1242.25	15.5	5229	5482.5

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5212.00	0.00	0.00	0.00	0.00	0.00	5482.49
4357.00	3.15	0.00	-214.00	-52.77	892.42	5395.52
4081.00	6.82	0.00	-326.00	-80.39	1214.28	5387.99
4000.00	9.44	0.00	-344.00	-84.83	1266.15	5345.31
4103.00	12.59	0.00	-307.00	-75.70	1168.10	5364.48
5171.00	16.26	0.00	-16.00	-3.95	58.97	5476.97
5229.00	18.36	0.00	0.00	0.00	0.00	5482.49

**********************<<< DATA SUMMARY >>>**********************

PROGRAM: mcc6 FILE: \milcrk\mcc6.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	15.6	5227	5482.5
2	7363.00	5179.00	1240.35	15.6	5354	5487.1
3	7394.00	5156.00	1238.40	15.7	5472	5478.5
4	7431.00	5139.00	1236.29	15.8	5597	5463.6
5	7467.00	5123.00	1234.39	15.8	5728	5469.8
6	7503.00	5107.00	1232.63	15.9	5844	5469.8
7	7539.00	5092.00	1230.75	16.0	5955	5455.6
8	7576.00	5076.00	1228.84	16.0	6064	5437.4
9	7337.00	5210.00	1242.25	16.1	5261	5482.5

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5227.00	0.00	0.00	0.00	0.00	0.00	5482.49
5354.00	5.25	0.00	31.00	7.64	-135.00	5487.05
5472.00	8.39	0.00	54.00	13.32	-273.55	5478.48
5597.00	12.59	0.00	71.00	17.51	-423.47	5463.56
5728.00	16.79	0.00	87.00	21.45	-558.47	5469.80
5844.00	20.98	0.00	103.00	25.40	-683.52	5469.79
5955.00	25.18	0.00	118.00	29.10	-817.10	5455.60
6064.00	29.38	0.00	134.00	33.04	-952.82	5437.36
5261.00	36.72	0.00	0.00	0.00	0.00	5482.49

Figure D5. Gravity Data, Line C

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcc7   FILE: \milcrk\mcc7.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	16.2	5261	5482.5
2	7349.00	5194.00	1241.11	16.3	5336	5486.7
3	7378.00	5166.00	1239.36	16.3	5449	5491.5
4	7413.00	5147.00	1237.17	16.4	5580	5482.3
5	7449.00	5131.00	1235.34	16.4	5705	5491.4
6	7485.00	5115.00	1233.28	16.5	5825	5478.8
7	7521.00	5100.00	1231.72	16.6	5924	5478.9
8	7467.00	5123.00	1234.39	16.6	5738	5462.2
9	7363.00	5179.00	1240.35	16.8	5384	5489.9
10	7337.00	5210.00	1242.25	16.8	5259	5482.5

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5261.00	0.00	0.00	0.00	0.00	0.00	5482.49
5336.00	-0.27	0.00	16.00	3.95	-81.00	5486.71
5449.00	-0.49	0.00	44.00	10.85	-205.34	5491.53
5580.00	-0.65	0.00	63.00	15.54	-360.94	5482.27
5705.00	-0.86	0.00	79.00	19.48	-490.97	5491.41
5825.00	-1.08	0.00	95.00	23.43	-637.34	5478.82
5924.00	-1.35	0.00	110.00	27.13	-748.18	5478.87
5738.00	-1.57	0.00	87.00	21.45	-558.47	5462.23
5384.00	-1.94	0.00	31.00	7.64	-135.00	5489.92
5259.00	-2.16	0.00	0.00	0.00	0.00	5482.49

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcc8   FILE: \milcrk\mcc8.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	50389

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	16.9	5261	5482.5
2	7558.00	5084.00	1229.97	17.0	6018	5457.7
3	7594.00	5068.00	1228.03	17.0	6125	5438.6
4	7631.00	5052.00	1225.94	17.1	6248	5425.5
5	7649.00	5044.00	1224.49	17.2	6333	5415.1
6	7612.00	5059.00	1227.03	17.3	6185	5431.0
7	7539.00	5092.00	1230.75	17.3	5971	5455.1
8	7413.00	5147.00	1237.17	17.4	5580	5474.4
9	7337.00	5210.00	1242.25	17.5	5269	5482.5

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5261.00	0.00	0.00	0.00	0.00	0.00	5482.49
6018.00	0.96	0.00	126.00	31.07	-872.53	5457.69
6125.00	1.68	0.00	142.00	35.02	-1010.36	5438.65
6248.00	3.12	0.00	158.00	38.96	-1158.87	5425.50
6333.00	4.32	0.00	166.00	40.93	-1261.89	5415.05
6185.00	5.28	0.00	151.00	37.24	-1081.42	5431.02
5971.00	6.24	0.00	118.00	29.10	-817.10	5455.10
5580.00	7.20	0.00	63.00	15.54	-360.94	5474.42
5269.00	8.64	0.00	0.00	0.00	0.00	5482.49

Figure D6. Gravity Data, Line C

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcc9x FILE: \milcrk\mcc9x.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	050789

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	14.6	5808	5482.5
2	7449.00	5131.00	1235.34	14.7	5527	4706.5
3	7521.00	5099.00	1231.72	14.8	5752	4699.5
4	7290.00	5296.00	1247.56	14.9	4721	4661.2
5	7273.00	5333.00	1249.53	15.0	4596	4656.3
6	7337.00	5210.00	1242.25	15.3	5814	5482.5

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5808.00	0.00	0.00	0.00	0.00	0.00	5482.49
5527.00	0.95	0.00	79.00	19.48	-490.97	4706.54
5752.00	1.74	0.00	111.00	27.37	-748.18	4699.45
4721.00	3.32	0.00	-86.00	-21.21	377.29	4661.21
4596.00	4.11	0.00	-123.00	-30.33	517.26	4656.25
5814.00	6.48	0.00	0.00	0.00	0.00	5482.49

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcc9x2 FILE: \milcrk\mcc9x2.gpf

BASE STATION (X,Y)	7337 5210
REFERENCE ELEV.	1242.25
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5076
LATITUDE	0462400
LONGITUDE	1181159
DATE	050789

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7337.00	5210.00	1242.25	15.3	5814	5482.5
2	7226.00	5443.00	1255.66	15.4	4189	4624.1
3	7203.00	5498.00	1257.91	15.5	4043	4614.0
4	7189.00	5535.00	1259.34	15.6	3962	4620.6
5	7337.00	5210.00	1242.25	15.9	5807	5482.5

-----------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5814.00	0.00	0.00	0.00	0.00	0.00	5482.49
4189.00	-1.43	0.00	-233.00	-57.46	952.82	4624.15
4043.00	-2.66	0.00	-288.00	-71.02	1112.68	4613.98
3962.00	-4.29	0.00	-325.00	-80.14	1214.28	4620.61
5807.00	-7.56	0.00	0.00	0.00	0.00	5482.49

Figure D7. Gravity Data, Line C

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd1　　FILE: \milcrk\mcd1.gpf

BASE STATION (X,Y)	7858 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7858.00	5395.00	1208.86	8.4	7231	7810.1
2	7863.00	5435.00	1208.75	8.7	7243	7830.6
3	7868.00	5474.00	1209.04	8.8	7231	7832.6
4	7874.00	5514.00	1209.23	8.9	7228	7842.4
5	7879.00	5553.00	1209.25	8.9	7247	7860.0
6	7885.00	5593.00	1209.24	9.0	7275	7885.0
7	7882.00	5573.00	1208.90	9.1	7281	7877.6
8	7874.00	5514.00	1209.23	9.2	7213	7851.4
9	7858.00	5395.00	1208.86	9.3	7162	7810.1

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
7231.00	0.00	0.00	0.00	0.00	0.00	7810.06
7243.00	-25.29	0.00	-40.00	-9.86	-7.81	7830.63
7231.00	-29.28	0.00	-79.00	-19.48	12.79	7832.65
7228.00	-38.59	0.00	-119.00	-29.34	26.29	7842.36
7247.00	-43.92	0.00	-158.00	-38.96	27.71	7860.01
7275.00	-49.24	0.00	-198.00	-48.83	27.00	7885.00
7281.00	-54.56	0.00	-178.00	-43.89	2.84	7877.58
7213.00	-63.88	0.00	-119.00	-29.34	26.29	7851.44
7162.00	-74.53	0.00	0.00	0.00	0.00	7810.06

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd2　　FILE: \milcrk\mcd2.gpf

BASE STATION (X,Y)	7858 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7858.00	5395.00	1208.86	9.3	7160	7810.1
2	7860.00	5415.00	1208.68	9.4	7225	7862.3
3	7866.00	5454.00	1208.86	9.5	7221	7860.9
4	7868.00	5474.00	1209.04	9.6	7208	7854.5
5	7871.00	5494.00	1208.95	9.6	7211	7846.2
6	7876.00	5534.00	1209.02	9.7	7229	7860.4
7	7863.00	5435.00	1208.75	9.8	7203	7837.3
8	7824.00	5301.00	1214.28	9.9	7189	8247.8
9	7858.00	5395.00	1208.86	10.0	7162	7810.1

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
7160.00	0.00	0.00	0.00	0.00	0.00	7810.06
7225.00	0.28	0.00	-20.00	-4.93	-12.78	7862.26
7221.00	0.51	0.00	-59.00	-14.55	0.00	7860.88
7208.00	0.74	0.00	-79.00	-19.48	12.79	7854.48
7211.00	0.91	0.00	-99.00	-24.41	6.39	7846.21
7229.00	1.25	0.00	-139.00	-34.28	11.37	7860.43
7203.00	1.53	0.00	-40.00	-9.86	-7.81	7837.29
7189.00	1.82	0.00	94.00	23.18	385.11	8247.85
7162.00	2.16	0.00	0.00	0.00	0.00	7810.06

Figure D8. Gravity Data, Line D

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd5 FILE: \milcrk\mcd5.gpf

BASE STATION (X,Y)	7853 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7858.00	5395.00	1208.86	10.0	7162	7210.1
2	7847.00	5357.00	1209.36	10.0	7156	7851.9
3	7832.00	5320.00	1212.71	10.1	6944	7876.9
4	7816.00	5283.00	1215.05	10.2	6803	7904.5
5	7801.00	5246.00	1219.12	10.3	6510	7894.3
6	7786.00	5209.00	1221.31	10.4	6354	7898.5
7	7860.00	5415.00	1208.68	10.5	7161	7828.7
8	7858.00	5395.00	1208.86	10.6	7121	7810.1

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
7162.00	0.00	0.00	0.00	0.00	0.00	7810.06
7156.00	-3.41	0.00	38.00	9.37	35.53	7851.88
6944.00	-10.22	0.00	75.00	18.49	273.55	7876.87
6803.00	-14.76	0.00	112.00	27.62	439.82	7904.51
6510.00	-22.71	0.00	149.00	36.74	729.00	7894.30
6354.00	-30.66	0.00	186.00	45.87	884.61	7898.49
7161.00	-37.47	0.00	-20.00	-4.95	-12.78	7828.73
7121.00	-44.28	0.09	0.00	0.00	0.00	7810.06

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd6 FILE: \milcrk\mcd6.gpf

BASE STATION (X,Y)	7858 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7856.00	5395.00	1208.86	10.6	7119	7810.1
2	7855.00	5375.00	1208.83	10.7	7151	7851.8
3	7847.00	5357.00	1209.36	10.8	7119	7862.0
4	7840.00	5338.00	1210.47	10.8	7061	7886.5
5	7826.00	5301.00	1214.28	10.9	6811	7898.9
6	7809.00	5264.00	1217.13	10.9	6613	7901.1
7	7786.00	5209.00	1221.31	11.1	6307	7887.4
8	7858.00	5395.00	1208.86	11.2	7092	7810.1

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
7119.00	0.00	0.00	0.00	0.00	0.00	7810.06
7151.00	-4.42	0.00	20.00	4.93	-2.13	7851.84
7119.00	-7.07	0.00	38.00	9.37	35.53	7862.03
7061.00	-10.60	0.00	57.00	14.06	114.39	7886.47
6811.00	-13.26	0.00	94.00	23.18	385.11	7898.94
6613.00	-17.67	0.00	131.00	32.30	587.60	7901.12
6307.00	-23.86	0.00	186.00	45.87	884.61	7887.37
7092.00	-29.16	0.00	0.00	0.00	0.00	7810.06

Figure D9. Gravity Data, Line D

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd5 FILE: \milcrk\mcd5.gpf

BASE STATION (X,Y)	7858 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

-------------------< FIELD DATA AND RESULTS >-------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7858.00	5395.00	1208.86	11.2	7090	7810.1
2	7778.00	5190.00	1221.20	11.3	6344	7937.5
3	7793.00	5227.00	1220.63	11.3	6349	7896.7
4	7767.00	5174.00	1221.70	11.4	6303	7940.8
5	7740.00	5145.00	1222.13	11.4	6294	7971.1
6	7716.00	5113.00	1222.78	11.5	6281	8014.6
7	7816.00	5283.00	1215.04	11.6	6757	7942.7
8	7858.00	5395.00	1208.86	11.6	7062	7810.1

-------------------< CORRECTIONS >-------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GR	G(UGALS)
7090.00	0.00	0.00	0.00	0.00	0.00	7810.06
6344.00	-5.87	0.00	205.00	50.55	876.78	7937.47
6349.00	-9.31	0.00	168.00	41.43	836.29	7896.74
6303.00	-13.96	0.00	221.00	54.50	912.31	79[illegible]9.80
6294.00	-16.28	0.00	250.00	61.65	942.87	7971.12
6281.00	-19.77	0.00	282.00	69.54	989.05	8016.64
6757.00	-25.59	0.00	112.00	27.62	439.11	7942.71
7062.00	-30.24	0.00	0.0[illegible]	0.00	0.00	7810.06

********************<<< DATA SUMMARY >>>********************

PROGRAM: mcd6 FILE: \milcrk\mcd6.gpf

BASE STATION (X,Y)	7858 5395
REFERENCE ELEV.	1208.86
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	7231
LATITUDE	0462400
LONGITUDE	1181159
DATE	050589

-------------------< FIELD DATA AND RESULTS >-------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7858.00	5395.00	1208.86	14.1	7073	7810.1
2	7754.00	5159.00	1221.92	14.2	6283	7940.3
3	7740.00	5145.00	1222.13	14.3	6287	7961.2
4	7696.00	5079.00	1222.58	14.4	6277	7996.4
5	7686.00	5061.00	1222.12	14.5	6315	8006.5
6	7706.00	5096.00	1222.77	14.5	6258	7981.2
7	7726.00	5130.00	1223.28	14.6	6216	7961.5
8	7858.00	5395.00	1208.86	14.7	7087	7810.1

-------------------< CORRECTIONS >-------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GR	G(UGALS)
7073.00	0.00	0.00	0.00	0.00	0.00	7810.06
6283.00	2.67	0.00	236.00	58.20	927.95	7940.27
6287.00	4.45	0.00	250.00	61.65	942.87	796[illegible]18
6277.00	6.67	0.00	316.00	77.92	[illegible]	7996.[illegible]1
6315.00	9.34	0.00	334.00	82.36	[illegible]	8006.5[illegible]
6258.00	10.67	0.00	299.00	73.73	988.34	7981.19
6216.00	12.90	0.00	265.[illegible]0	65.35	1[illegible]4.58	7961.46
7087.00	15.12	0.00	0.00	0.00	0.00	7810.06

Figure D10. Gravity Data, Line D

********************<<< DATA SUMMARY >>>********************

PROGRAM: mce1   FILE: \milcrk\mce1.gpf

BASE STATION (X,Y)	7567 5199
REFERENCE ELEV.	1230.45
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5850
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7567.00	5109.00	1230.45	9.8	5850	6318.5
2	7531.00	5125.00	1232.23	9.9	5749	6334.7
3	7494.00	5142.00	1234.00	10.0	5624	6323.7
4	7458.00	5158.00	1236.25	10.1	5481	6327.9
5	7421.00	5175.00	1238.07	10.3	5382	6347.9
6	7567.00	5109.00	1230.45	10.7	5830	6318.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5850.00	0.00	0.00	0.00	0.00	0.00	6318.47
5749.00	-2.80	0.00	-16.00	-3.95	126.48	6334.71
5624.00	-5.20	0.00	-33.00	-8.14	252.24	6323.67
5481.00	-8.00	0.00	-49.00	-12.08	412.11	6327.94
5382.00	-11.20	0.00	-66.00	-16.28	540.01	6347.92
5830.00	-21.40	0.00	0.00	0.00	0.00	6318.47

********************<<< DATA SUMMARY >>>********************

PROGRAM: mce2   FILE: \milcrk\mce2.gpf

BASE STATION (X,Y)	7567 5109
REFERENCE ELEV.	1230.45
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5850
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7567.00	5109.00	1230.45	10.7	5830	6318.5
2	7549.00	5117.00	1231.02	10.7	5813	6336.7
3	7513.00	5134.00	1232.66	10.8	5696	6318.7
4	7494.00	5142.00	1234.00	10.9	5616	6322.6
5	7476.00	5150.00	1235.38	10.9	5542	6313.5
6	7448.00	5166.00	1237.25	11.0	5403	6309.7
7	7421.00	5175.00	1238.05	11.0	5385	6342.9
8	7403.00	5183.00	1238.36	11.1	5365	6337.4
9	7385.00	5191.00	1239.53	11.1	5297	6341.2
10	7567.00	5109.00	1230.45	11.3	5860	6318.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5830.00	0.00	0.00	0.00	0.00	0.00	6318.47
5815.00	1.96	0.00	-8.00	-1.97	40.50	6336.68
5696.00	5.89	0.00	-25.00	-6.16	157.03	6318.71
5616.00	8.84	0.00	-33.00	-8.14	252.24	6322.60
5542.00	12.76	0.00	-41.00	-10.11	328.97	6313.50
5403.00	16.69	0.00	-57.00	-14.06	483.16	6309.69
5385.00	13.66	0.00	-66.00	-16.28	540.01	6342.91
5365.00	22.58	0.00	-74.00	-18.25	562.03	6337.43
5297.00	26.51	0.00	-82.00	-20.22	645.16	6341.22
5860.00	32.40	0.00	0.00	0.00	0.00	6318.47

Figure D11. Gravity Data, Line E

```
******************<<<   DATA SUMMARY   >>>*******************

PROGRAM: mce3            FILE: \milcrk\mce3.gpf

BASE STATION (X,Y)     7567  5109
REFERENCE ELEV.        1230.45
DENSITY                1.8
GRID ROTATION          0
METER FACTOR           1.00006
REFERENCE READING      5850
LATITUDE               0462400
LONGITUDE              1181159
DATE                   050489
```

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7567.00	5109.00	1230.45	11.3	5860	6318.5
2	7604.00	5093.00	1229.33	11.3	5909	6296.8
3	7640.00	5076.00	1227.35	11.4	6021	6282.2
4	7658.00	5068.00	1225.61	11.4	6129	6277.9
5	7622.00	5084.00	1228.47	11.4	5959	6294.9
6	7549.00	5117.00	1231.02	11.5	5814	6312.3
7	7585.00	5101.00	1229.97	11.6	5881	6315.0
8	7604.00	5093.00	1229.33	11.6	5911	6304.9
9	7567.00	5109.00	1230.45	11.7	5852	6318.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5860.00	0.00	0.00	0.00	0.00	0.00	6318.47
5909.00	-1.00	0.00	16.00	3.95	-79.58	6296.76
6021.00	-1.99	0.00	33.00	8.14	-220.26	6282.23
6129.00	-2.66	0.00	41.00	10.11	-343.89	6277.89
5959.00	-3.99	0.00	25.00	6.16	-140.68	6294.87
5814.00	-4.98	0.00	-8.00	-1.97	40.50	6312.38
5881.00	-5.98	0.00	8.00	1.97	-34.10	6315.00
5911.00	-6.98	0.00	16.00	3.95	-79.58	6304.90
5852.00	-8.64	0.00	0.00	0.00	0.00	6318.47

```
******************<<<   DATA SUMMARY   >>>*******************

PROGRAM: mce4            FILE: \milcrk\mce4.gpf

BASE STATION (X,Y)     7567  5109
REFERENCE ELEV.        1230.45
DENSITY                1.8
GRID ROTATION          0
METER FACTOR           1.00006
REFERENCE READING      5850
LATITUDE               0462400
LONGITUDE              1181159
DATE                   050489
```

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7567.00	5109.00	1230.45	11.7	5852	6318.5
2	7531.00	5125.00	1232.23	11.8	5756	6337.3
3	7467.00	5123.00	1234.39	11.9	5643	6369.2
4	7476.00	5150.00	1235.08	11.9	5576	6339.2
5	7640.00	5076.00	1227.35	12.0	6023	6291.0
6	7567.00	5109.00	1230.45	12.1	5852	6318.5

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5852.00	0.00	0.00	0.00	0.00	0.00	6318.47
5756.00	0.00	0.00	-16.00	-3.95	126.48	6337.31
5643.00	0.00	0.00	-14.00	-3.45	279.95	6369.23
5576.00	0.00	0.00	-41.00	-10.11	328.97	6339.23
6023.00	0.00	0.00	33.00	8.14	-220.26	6291.04
5852.00	0.00	0.00	0.00	0.00	0.00	6318.47

Figure D12. Gravity Data, Line E

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcf1 FILE: \milcrt\mcf1.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00008
REFERENCE READING	5348
LATITUDE	0462600
LONGITUDE	1181159
DATE	050489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	13.6	5348	5776.3
2	7695.00	5291.00	1237.15	13.6	5334	5718.4
3	7706.00	5289.00	1236.95	13.7	5344	5714.3
4	7715.00	5328.00	1236.57	13.8	5368	5705.2
5	7725.00	5366.00	1236.06	13.8	5392	5685.7
6	7736.00	5405.00	1235.25	13.9	5444	5673.5
7	7747.00	5443.00	1234.43	13.9	5505	5673.3
8	7758.00	5482.30	1233.83	13.9	5555	5675.3
9	7715.00	5328.00	1236.57	14.0	5365	5703.1
10	7688.00	5252.00	1237.51	14.1	5321	5746.3
11	7682.00	5212.00	1237.48	14.1	5346	5776.3

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/BB	G(UGALS)
5348.00	0.00	0.00	0.00	0.00	0.00	5776.27
5334.00	-0.20	0.00	-79.00	-19.48	-25.44	5718.42
5344.00	-0.41	0.00	-77.00	-18.99	-39.07	5714.29
5368.00	-0.61	0.00	-116.00	-28.61	-64.66	5705.21
5392.00	-0.81	0.00	-154.00	-37.98	-100.89	5685.76
5444.00	-1.01	0.00	-193.00	-47.59	-159.07	5673.51
5505.00	-1.15	0.06	-231.00	-56.96	-216.70	5673.32
5555.00	-1.42	0.06	-270.00	-66.58	-259.34	5675.34
5365.00	-1.76	0.00	-116.00	-28.61	-64.66	5703.12
5321.00	-1.96	0.00	-20.00	-4.95	2.13	5746.27
5346.00	-2.16	0.00	0.00	0.00	0.0	—— —

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcf2 FILE: \milcrt\mcf2.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00008
REFERENCE READING	5348
LATITUDE	0462600
LONGITUDE	1181159
DATE	050489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	14.2	5343	5776.3
2	7699.00	5270.00	1237.02	14.2	5361	5747.1
3	7709.00	5309.00	1236.81	14.3	5366	5726.2
4	7720.00	5347.00	1236.34	14.4	5395	5710.6
5	7731.00	5386.00	1235.62	14.4	5437	5695.7
6	7735.00	5405.00	1235.25	14.4	5464	5690.9
7	7742.00	5424.00	1234.85	14.5	5485	5678.8
8	7752.00	5463.00	1234.08	14.6	5555	5689.3
9	7695.00	5291.00	1237.15	14.6	5351	5727.9
10	7682.00	5212.00	1237.48	14.8	5360	5776.3

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/BB	G(UGALS)
5343.00	0.00	0.00	0.00	0.00	0.00	5776.27
5361.00	1.62	0.00	-58.00	-14.30	-32.58	5747.11
5366.00	3.26	0.00	-97.00	-23.92	-47.60	5726.19
5395.00	5.40	0.00	-135.00	-33.29	-81.00	5710.58
5437.00	7.02	0.00	-174.00	-42.91	-132.16	5695.71
5464.00	8.64	0.00	-193.00	-47.59	-159.87	5690.86
5485.00	10.26	0.00	-212.00	-52.28	-188.29	5678.81
5555.00	12.42	0.00	-251.00	-61.90	-261.58	5689.35
5351.00	14.04	0.00	-79.00	-19.48	-25.44	5727.96
5360.00	18.36	0.00	0.00	0.00	0.00	5776.27

Figure D13. Gravity Data, Line F

<<< DATA SUMMARY >>>

PROGRAM: mcf4 FILE: \milcrk\mcf4.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00008
REFERENCE READING	5348
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

< FIELD DATA AND RESULTS >

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	15.4	5417	5776.3
2	7675.00	5173.00	1233.95	15.5	5659	5792.7
3	7671.00	5133.00	1231.95	15.6	5808	5816.7
4	7666.00	5094.00	1228.43	15.6	6019	5803.9
5	7668.00	5114.00	1230.44	15.7	5873	5781.4
6	7677.00	5195.00	1236.91	15.8	5457	5770.7
7	7682.00	5212.00	1237.48	15.9	5433	5776.3

< CORRECTIONS >

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5417.00	0.00	0.00	0.00	0.00	0.00	5776.27
5659.00	3.78	0.00	39.00	9.62	-250.82	5792.67
5808.00	7.02	0.00	79.00	19.48	-394.34	5816.70
6019.00	8.64	0.00	118.00	29.10	-643.02	5803.91
5873.00	11.34	0.00	98.00	24.17	-500.21	5781.40
5457.00	12.96	0.00	19.00	4.69	-48.50	5770.70
5433.00	17.28	0.00	0.00	0.00	0.00	5776.27

<<< DATA SUMMARY >>>

PROGRAM: mcf6 FILE: \milcrk\mcf6.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00008
REFERENCE READING	5348
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

< FIELD DATA AND RESULTS >

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	16.1	5469	5776.3
2	7759.00	5502.00	1233.75	16.2	5698	5687.0
3	7760.00	5542.00	1233.40	16.3	5704	5681.8
4	7761.00	5582.00	1233.82	16.3	5722	5701.3
5	7758.00	5482.00	1233.85	16.4	5663	5664.3
6	7762.00	5622.00	1233.73	16.4	5771	5740.6
7	7763.00	5662.00	1233.63	16.5	5787	5741.6
8	7764.00	5702.00	1233.17	16.5	5866	5785.4
9	7762.00	5622.00	1233.75	16.4	5741	5710.9
10	7682.00	5212.00	1237.48	16.7	5459	5776.3

< CORRECTIONS >

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5469.00	0.00	0.00	0.00	0.00	0.00	5776.27
5698.00	-1.35	0.00	-290.00	-71.51	-266.45	5687.00
5704.30	-2.36	0.00	-330.00	-81.38	-269.29	5681.78
5722.00	-3.06	0.00	-370.00	-91.24	-268.05	5701.27
5663.00	-4.39	0.00	-270.00	-66.58	-259.34	5664.27
5771.00	-5.74	0.00	-410.00	-101.10	-266.45	5740.64
5787.00	-6.41	0.00	-450.00	-110.97	-273.55	5741.63
5866.00	-7.43	0.00	-490.00	-120.83	-306.23	5785.42
5741.00	-8.44	0.00	-410.00	-101.10	-266.45	5710.96
5459.00	-10.80	0.00	0.00	0.00	0.00	5776.27

Figure D14. Gravity Data, Line F

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcf7 FILE: \milcrk\mcf7.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00006
REFERENCE READING	5348
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

-------------------< FIELD DATA AND RESULTS >-------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	16.7	5459	5776.3
2	7759.00	5522.00	1253.69	16.8	5772	5766.4
3	7760.00	5562.00	1253.77	16.8	5761	5749.2
4	7761.00	5602.00	1253.92	16.8	5791	5781.3
5	7762.00	5642.00	1253.65	16.9	5862	5815.8
6	7763.00	5682.00	1253.26	16.9	5905	5835.0
7	7764.00	5702.00	1253.17	16.9	5953	5852.8
8	7760.00	5582.00	1253.82	17.0	5791	5772.9
9	7742.00	5426.00	1254.85	17.8	5612	5689.2
10	7682.00	5212.00	1237.48	17.3	5673	5776.3

-------------------< CORRECTIONS >-------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5459.00	0.00	0.00	0.00	0.00	0.00	5776.27
5772.00	2.24	0.00	-310.00	-76.44	-269.29	5766.36
5761.00	3.36	0.00	-350.00	-86.31	-263.68	5749.18
5791.00	4.48	0.00	-390.00	-96.17	-252.36	5781.26
5862.00	6.16	0.00	-430.00	-106.06	-283.50	5815.85
5905.00	7.28	0.00	-470.00	-115.90	-299.86	5834.96
5953.00	8.40	0.00	-490.00	-120.83	-306.23	5852.76
5791.00	10.64	0.00	-370.00	-91.24	-260.85	5772.92
5612.00	11.76	0.00	-212.98	-52.28	-188.29	5689.19
5673.00	15.12	0.00	0.00	0.00	0.00	5776.27

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcfx FILE: \milcrk\mcf8.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.00006
REFERENCE READING	5348
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

-------------------< FIELD DATA AND RESULTS >-------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	16.7	5296	5776.3
2	7671.00	5133.00	1231.95	16.8	5637	5767.6
3	7699.00	5270.00	1237.02	16.9	5303	5734.7
4	7759.00	5522.00	1253.69	17.1	5535	5708.1
5	7761.00	5602.00	1253.92	17.1	5565	5715.5
6	7764.00	5702.00	1233.17	17.2	5720	5805.0
7	7682.00	5212.00	1237.48	17.4	5296	5776.3

-------------------< CORRECTIONS >-------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5296.00	0.00	0.00	0.00	0.00	0.00	5776.27
5637.00	0.00	0.00	79.00	19.48	-394.34	5767.55
5303.00	0.00	0.00	-58.00	-14.30	-32.68	5734.68
5535.00	0.00	0.00	-310.00	-76.44	-269.39	5708.11
5565.00	0.00	0.00	-390.00	-96.17	-252.94	5715.53
5720.00	0.00	0.00	-490.00	-120.83	-306.23	5805.08
5296.00	0.00	0.00	0.00	0.00	0.00	5776.27

Figure D15. Gravity Data, Line F

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mcf3x FILE: \milcrk\mcf5.gpf

BASE STATION (X,Y)	7682 5212
REFERENCE ELEV.	1237.48
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	5348
LATITUDE	0462400
LONGITUDE	1181159
DATE	050489

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	7682.00	5212.00	1237.48	14.8	5359	5776.3
2	7677.00	5193.00	1236.91	14.8	5394	5769.8
3	7673.00	5153.00	1233.14	14.9	5646	5777.2
4	7668.00	5114.00	1230.44	15.0	5837	5792.8
5	7664.00	5074.00	1226.50	15.1	6117	5815.0
6	7640.00	5076.00	1227.35	15.2	6080	5826.5
7	7688.00	5232.00	1237.51	15.3	5385	5750.8
8	7682.00	5212.00	1237.48	15.4	5417	5776.3

-----------------< CORRECTIONS >-----------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
5359.00	0.00	0.00	0.00	0.00	0.00	5776.27
5394.00	8.47	0.00	19.00	4.69	-40.50	5769.79
5646.00	15.24	0.00	59.00	14.55	-308.37	5777.20
5837.00	23.70	0.00	98.00	24.17	-500.21	5792.80
6117.00	33.86	0.00	138.00	34.03	-780.15	5814.98
6080.00	42.33	0.00	136.00	33.54	-719.76	5826.45
5385.00	50.79	0.00	-20.00	-4.93	2.13	5750.76
5417.00	62.64	0.00	0.00	0.00	0.00	5776.27

Figure D16. Gravity Data, Line F

```
*******************<<<   DATA SUMMARY   >>>*******************

PROGRAM: mch1               FILE: \milcrk\mch1.gpf

BASE STATION (X,Y)     70  0
REFERENCE ELEV.        1188.94
DENSITY                1.8
GRID ROTATION          0
METER FACTOR           1.08008
REFERENCE READING      8652
LATITUDE               0462400
LONGITUDE              1181159
DATE                   050689
```

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	0.00	1188.94	8.9	8652	9344.9
2	100.00	30.00	1189.15	9.0	8667	9371.9
3	80.00	30.00	1189.06	9.1	8677	9379.0
4	60.00	30.00	1189.09	9.1	8673	9379.5
5	30.00	50.00	1190.75	9.2	8609	9425.4
6	30.00	20.00	1190.29	9.3	8603	9395.6
7	40.00	100.00	1190.99	9.3	8661	9490.3
8	80.00	100.00	1190.86	9.4	8642	9464.5
9	70.00	0.00	1188.94	9.5	8631	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8652.00	0.00	0.00	0.00	0.00	0.00	9344.85
8667.00	-3.34	0.00	-30.00	-7.40	14.93	9371.92
8677.00	-6.00	0.00	-30.00	-7.40	8.53	9379.00
8673.00	-8.67	0.00	-30.00	-7.40	10.66	9379.47
8609.00	-10.67	0.00	-50.00	-12.33	123.61	9425.36
8603.00	-12.68	0.00	-20.00	-4.93	95.93	9395.60
8661.00	-14.68	0.00	-100.00	-24.66	145.66	9490.25
8642.00	-18.68	0.00	-100.00	-24.66	136.42	9464.50
8631.00	-22.68	0.00	0.00	0.00	0.00	9344.85

```
*******************<<<   DATA SUMMARY   >>>*******************

PROGRAM: mch2               FILE: \milcrk\mch2.gpf

BASE STATION (X,Y)     70  0
REFERENCE ELEV.        1188.94
DENSITY                1.8
GRID ROTATION          0
METER FACTOR           1.08008
REFERENCE READING      8652
LATITUDE               0462400
LONGITUDE              1181159
DATE                   050689
```

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	0.00	1188.94	9.5	8629	9344.9
2	30.00	70.00	1191.13	9.6	8602	9457.6
3	50.00	80.00	1189.08	9.6	8666	9395.6
4	100.00	30.00	1189.15	9.7	8629	9366.5
5	30.00	0.00	1190.04	9.8	8555	9361.9
6	10.00	30.00	1193.14	9.9	8404	9421.1
7	40.00	100.00	1190.99	10.0	8624	9494.5
8	70.00	0.00	1188.94	10.1	8592	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8629.00	0.00	0.00	0.00	0.00	0.00	9344.85
8602.00	-3.53	0.00	-70.00	-17.26	155.61	9457.56
8666.00	-8.23	0.00	-30.00	-7.40	9.95	9395.59
8629.00	-14.10	0.00	-30.00	-7.40	14.93	9366.49
8555.00	-18.81	0.00	0.00	0.00	78.16	9361.90
8404.00	-28.21	0.00	-30.00	-7.40	298.43	9421.07
8624.00	-34.09	0.00	-100.00	-24.66	145.66	9494.54
8592.00	-39.96	0.00	0.00	0.00	0.00	9344.85

Figure D17. Gravity Data, Line H

********************<<< DATA SUMMARY >>>********************

PROGRAM: mch3 FILE: \milcrk\mch3.gpf

BASE STATION (X,Y)	70 0
REFERENCE ELEV.	1188.94
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	8652
LATITUDE	0462400
LONGITUDE	1181159
DATE	050689

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	0.00	1188.94	10.1	8591	9344.9
2	10.00	100.00	1195.40	10.2	8449	9482.1
3	60.00	100.00	1190.88	10.3	8597	9462.1
4	60.00	30.00	1189.09	10.3	8599	9352.7
5	30.00	80.00	1191.41	10.4	8534	9433.7
6	100.00	100.00	1191.03	10.4	8573	9442.7
7	10.00	30.00	1193.14	10.5	8363	9381.8
8	20.00	100.00	1192.37	10.5	8515	9472.8
9	70.00	100.00	1190.86	10.6	8591	9446.4
10	70.00	0.00	1188.94	10.6	8602	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8591.00	0.00	0.00	0.00	0.00	0.00	9344.85
8449.00	1.64	0.00	-100.00	-26.66	316.90	9482.08
8597.00	2.46	0.00	-100.00	-26.66	137.85	9462.06
8599.00	4.10	0.00	-30.00	-7.40	10.66	9352.66
8534.00	5.33	0.00	-80.00	-19.73	175.51	9433.74
8573.00	6.55	0.00	-100.00	-26.66	148.51	9442.70
8363.00	7.78	0.00	-30.00	-7.40	298.43	9381.84
8515.00	9.01	0.00	-100.00	-26.66	263.71	9472.81
8591.00	10.26	0.00	-100.00	-26.66	136.42	9446.38
8602.00	11.98	0.00	0.00	0.00	0.00	9344.85

********************<<< DATA SUMMARY >>>********************

PROGRAM: mch4 FILE: \milcrk\mch4.gpf

BASE STATION (X,Y)	70 0
REFERENCE ELEV.	1188.94
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	8652
LATITUDE	0462400
LONGITUDE	1181159
DATE	050689

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	1.00	1188.94	10.6	8602	9344.9
2	90.00	30.00	1189.05	10.7	8611	9356.1
3	30.00	60.00	1190.97	10.8	8544	9413.6
4	10.00	100.00	1193.40	10.8	8449	9474.3
5	90.00	100.00	1190.85	10.8	8601	9458.2
6	30.00	10.00	1190.18	10.9	8503	9327.8
7	30.00	50.00	1190.75	10.9	8533	9391.6
8	30.00	40.00	1190.51	11.0	8541	9386.2
9	30.00	90.00	1191.54	11.0	8555	9463.0
10	30.00	30.00	1189.39	11.1	8558	9329.2
11	70.00	0.00	1188.94	11.1	8594	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8602.00	8.36	0.00	-1.00	-0.25	0.00	9344.88
8611.00	7.53	0.00	-30.00	-7.40	7.82	9356.11
8544.00	6.69	0.00	-60.00	-14.80	144.24	9413.60
8449.00	6.13	0.00	-100.00	-24.66	316.90	9474.35
8601.00	5.30	0.00	-100.00	-24.66	135.71	9458.17
8503.00	4.46	0.00	-10.00	-2.47	88.11	9327.75
8533.00	3.62	0.00	-50.00	-12.33	128.61	9391.62
8541.00	3.07	0.00	-40.00	-9.86	111.56	9386.24
8555.00	2.23	0.00	-90.00	-22.19	184.74	9463.05
8558.00	1.39	0.00	-30.00	-7.40	31.98	9329.16
8594.00	0.00	0.00	0.00	0.00	0.00	9344.85

Figure D18. Gravity Data, Line H

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mch5 FILE: \milcrk\mch5.gpf

BASE STATION (X,Y)	70 0
REFERENCE ELEV.	1188.94
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	8652
LATITUDE	0462400
LONGITUDE	1181159
DATE	050689

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	0.00	1188.94	11.2	8594	9344.9
2	70.00	30.00	1188.97	11.2	8599	9357.1
3	50.00	100.00	1190.87	11.2	8595	9482.6
4	30.00	70.00	1191.13	11.3	8539	9466.1
5	20.00	30.00	1191.46	11.3	8471	9438.0
6	30.00	100.00	1191.58	11.4	8476	9446.7
7	30.00	90.00	1191.54	11.4	8466	9453.7
8	0.00	100.00	1194.53	11.4	8258	9457.1
9	40.00	30.00	1189.45	11.5	8503	9396.2
10	70.00	0.00	1188.94	11.5	8471	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8594.00	0.00	0.00	0.00	0.00	0.00	9344.85
8599.00	-12.08	0.00	-30.00	-7.40	2.13	9357.07
8595.00	-24.15	0.00	-100.00	-24.66	137.14	9482.56
8539.00	-42.27	0.00	-70.00	-17.26	155.61	9466.07
8471.00	-54.35	0.00	-30.00	-7.40	179.05	9438.01
8476.00	-66.42	0.00	-100.00	-24.66	187.58	9446.75
8466.00	-84.54	0.00	-90.00	-22.19	184.74	9453.69
8258.00	-102.66	0.00	-100.00	-24.66	397.19	9457.13
8503.00	-120.77	0.00	-30.00	-7.40	36.24	9396.18
8471.00	-132.85	0.00	0.00	0.00	0.00	9344.85

*******************<<< DATA SUMMARY >>>*******************

PROGRAM: mch6 FILE: \milcrk\mch6.gpf

BASE STATION (X,Y)	70 0
REFERENCE ELEV.	1188.94
DENSITY	1.8
GRID ROTATION	0
METER FACTOR	1.08008
REFERENCE READING	8652
LATITUDE	0462400
LONGITUDE	1181159
DATE	050689

------------------< FIELD DATA AND RESULTS >------------------

STATION	COORD(X,Y)		ELEV	TIME	READING	G(UGALS)
1	70.00	0.00	1188.94	11.6	8472	9344.9
2	50.00	0.00	1188.93	11.6	8484	9356.1
3	0.00	0.00	1193.71	11.7	8199	9386.9
4	0.00	50.00	1193.62	11.8	8282	9456.5
5	0.00	70.00	1193.66	11.8	8289	9460.6
6	30.00	80.00	1191.41	11.9	8452	9472.7
7	50.00	70.00	1190.26	11.9	8505	9449.7
8	70.00	70.00	1190.00	12.0	8515	9441.0
9	70.00	0.00	1188.94	12.1	8481	9344.9

------------------< CORRECTIONS >------------------

READING	DRIFT	TIDE	DEPART	LATDE	FA/GB	G(UGALS)
8472.00	0.00	0.00	0.00	0.00	0.00	9344.85
8484.00	1.01	0.00	0.00	0.00	-0.70	9356.11
8199.00	2.01	0.00	0.00	0.00	338.92	9386.90
8282.00	3.35	0.00	-50.00	-12.33	332.53	9456.48
8289.00	4.69	0.00	-70.00	-17.26	335.37	9460.62
8452.00	6.37	0.00	-80.00	-19.73	175.51	9472.66
8505.00	7.37	0.00	-70.00	-17.26	93.79	9449.65
8515.00	8.38	0.00	-70.00	-17.26	75.32	9440.97
8481.00	9.72	0.00	0.00	0.00	0.00	9344.85

Figure D19. Gravity Data, Line H